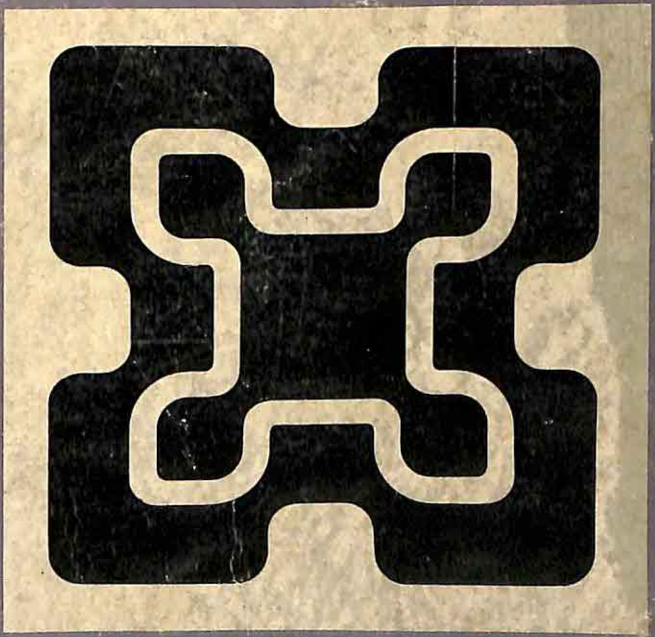
New trends in integrated science teaching

Volume II

The teaching of basic sciences

Integrated science



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New trends in integrated science teaching

Volume II

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PREFACE

This publication "New Trends in Integrated Science Teaching" (Volume 2) forms part of Unesco's programme in integrated science teaching. This programme was launched in 1969 and is carried out in close collaboration with other international and bi-lateral aid organizations working in this field. There were three principal reasons for starting the programme:—

1. It has become increasingly apparent that science must be an element in the general education of all children. However, the majority of children in many parts of the world do not get beyond primary school. Clearly, science needs to be introduced as an element in primary education and such science must of necessity be of an integrated type—or perhaps undifferentiated would be a better term.
2. At secondary level, if science is to be an element of general education, at least in the lower cycle of secondary education, some form of integrated science teaching is likely to be more appropriate than courses in the separate disciplines of physics, chemistry and biology.
3. Integrated science teaching at primary and secondary levels provides a sound basis for continuing science education either in specialist subjects or further integrated science.

Unesco's programme was therefore launched with a particular emphasis on primary schools, the lower grades of secondary schools and the training of teachers for these levels of the educational system. It consists essentially of four parts:—

1. A series of publications on integrated science teaching.
2. A series of regional, sub-regional and national integrated science teaching workshops.
3. Experimental projects for the development of new methods and materials for integrated science teaching at the primary and lower secondary levels and for teacher training.
4. Technical services to Unesco's member states through Unesco field experts concerned with integrated science teaching.

This volume is composed of commissioned manuscripts and of examples of integrated science teaching drawn from projects or teaching schemes ranging from elementary to university level. It presents a thorough analysis, review and exemplification of trends in integrated science teaching. Chapters 1—9 consider in detail certain distinct aspects of the teaching of science in an integrated way as revealed by the literature on the subject throughout the world and the accounts given by experimental projects and at international conferences. Chapter 10 gives examples. The important question of teacher education for integrated science has not been considered in detail because a major publication "New Trends in the Education of Teachers for Integrated Science" will be produced in 1973, following the Conference on that theme sponsored by the ICSU Committee on Science Teaching, with the support of Unesco, to be held at the University of Maryland, U.S.A., in April 1973.

The authors of the chapters have attempted a wide geographical coverage of material and ideas. Two meetings have enabled them to comment on each other's contributions and to attempt to bring the manuscripts together to form a unified whole. Complete unanimity is impossible, even undesirable, in a field growing and changing as rapidly as is integrated science teaching. Its limits and very definition are still in dispute and, rather than trying to pin integrated science down, the chapters of this volume display some of the characteristics of integrated science in action. It is hoped that they and their bibliographies will form a valuable and previously non-existent summary of world-wide trends in major aspects of integrated science teaching, together with a statement of the current position.

Integrated science teaching is developing more quickly in some countries than in others and inevitably projects and activities in some parts of the world are given greater prominence than others. In some areas small groups or individuals are making striking changes in their curricula and teaching methods without attracting wide publicity. By their very nature they escape the notice of reviews such as this but their value is inestimable.

This volume with its reference to links with other areas of the curriculum including language teaching, social studies, agriculture and technology is intended principally to provide information and inspiration for those concerned with science curriculum planning and design. It will also be useful to all concerned with the education of teachers: lecturers, students and practising teachers attending refresher courses. Very many questions are raised which could be discussed at workshops in integrated science teaching or could be used to initiate meaningful educational research.

This volume was prepared in consultation with the Committee on Science Teaching of the International Council of Scientific Unions. The Chairman, Professor M. Matyas (Czechoslovakia) has written the introduction and the Secretary, D. Chisman (United Kingdom) has offered advice and assistance in many ways. Particular appreciation is expressed to those who prepared articles and to the project leaders, editors and publishers who supplied the information on which articles are based and allowed the use of copyright material. Unesco acknowledges with gratitude the work of the Editor, P.E. Richmond of the University of Southampton (United Kingdom).

The views expressed are the responsibility of the authors and of the editor and do not necessarily reflect the views of Unesco.

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Dr. Alberto Baez
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1 Dec. 1971

Dear Alberto

This is to let you know that I am in fundamental agreement with you as regards the importance of the integrated teaching of science. I would even go further than you, and propose integrating not only various disciplines of science, but integrating it with history, and the whole of human culture. Moreover, I consider it as important in the formation of characters, because science means realistic, systematic and patient thinking, as opposed to convenient myths and daydreams. Properly taught, it ought to convey not only the knowledge of Nature, but also the love of Nature.

Yours sincerely
Dennis Gabor

Dr. A. V. Baez

Professor D. Gabor

This letter is part of a correspondence between Professor D. Gabor, Nobel Prizewinner in Physics, 1971 and Dr. A. V. Baez, formerly Director of the Division of Science Teaching, Unesco, and initiator of the "New Trends" series.

Introduction

THE ROLE OF THE I.C.S.U. COMMITTEE IN THE TEACHING OF SCIENCE

M. Matyas, Chairman of the I.C.S.U. Committee
Czechoslovak Academy of Sciences

In the history of science there are periods in which qualitative changes occur in scientific progress. These changes influence many of man's institutions and activities including the philosophy and practice of education. The latest qualitative change in scientific developments has taken place only recently, in the middle of the twentieth century. Individual fields of science have begun to overlap, the borderlines are disappearing and the ancient, empirical ways of technology are being influenced more and more by the work of scientists. Much scientific work has ceased to be the concern of individuals and calls, to an increasing extent, for substantial financial support, for decisions from the highest political authorities and for cooperation amongst teams of scientists. The social, economic and political decisions and problems which arise from today's science and technology are accompanied by pedagogic questions of practical importance to all who work in science education. It has become clear that the classical concept of education in which knowledge of the natural world is acquired partly in physics courses, partly in chemistry, partly in biology etc., is inadequate because it does not correspond to the present state of scientific progress or to the needs of modern society.

It is also clear that the pedagogic issues are extremely complex for they are concerned not only with education in school or college but also with such topics as the exchange of information and opinion between the teaching community and scientists and with the new and powerful tools of educational technology and teaching media. Questions raised in these and similar areas cannot be answered from within a single science, solutions must be sought, at the very least, in dialogues between the sciences.

In this situation the International Council of Scientific Unions (I.C.S.U.) is making a substantial contribution to attempt to solve questions concerning this new concept in education. First, the Inter-Union Commission for Science Teaching was established. Then, in 1969, I.C.S.U. set up its own Committee on the Teaching of Science. This committee includes representatives of the individual scientific unions and five or six specially invited scientists nominated by the I.C.S.U. Executive Committee. The latter have a particular interest in and experience of science teaching, often in several parts of the world. In this brief introduction I shall try to describe the role of the I.C.S.U. Committee on the Teaching of Science and the part it has to play in the development of a modern concept of education.

The Inter-Union Commission adopted a policy which has proved highly productive in terms of further development. It made the assumption that the natural sciences can be taught in a unified way. Building on this premiss the I.C.S.U. Committee has since been actively supporting and advocating the so-called "integrated" approach to science teaching. In 1968 an international conference was organised in Varna (Bulgaria) where the central question was "Why integrate science teaching?" The aims of integrated science teaching and the relations between coordinated and integrated teaching were defined at this conference and listed in its proceedings [1]. At the same time outline plans for the further development of this educational concept were made.

The Committee accepted that one of the best approaches to science in a modern educational system is an integrated one. It was encouraged in this view by the knowledge that integrated science has already been used successfully in some countries, notably the U.S.A., Australia and the United Kingdom but also in Africa, Asia and Latin America. In Europe too several countries are paying increasing attention to the possibilities of integrated science e.g. France, U.S.S.R., the Netherlands, Czechoslovakia etc. Most primary (elementary) science is integrated but the secondary and tertiary establishments are also now developing integrated courses as is evidenced in many chapters of this volume. Experience indicates that integrated science corresponds well to the present developments in science and to the needs of today's society. The ways in which it serves and reflects the thought and activities in science and society are also well described in this volume and its predecessor. They can be summarised as follows:

Integrated science teaching accentuates the unity of science, enables us to understand the position of man in nature and in today's society; it introduces young people to interdisciplinary problems, accentuates the role of observation, introduces the use of scientific methods in solving practical problems. It is believed that through integrated science young people will be better prepared for practical life and that they will gain a better fundamental knowledge from which they can build and, if they wish at some time, specialize in a single science.

During the last few years it has become apparent that the education of teachers for integrated science teaching is an important issue raising many questions. The I.C.S.U. Committee has arranged a conference to be held in the University of Maryland (U.S.A.) during April 1973 entitled "Education of Teachers for Integrated Science–Teaching Science for Today's Society". The conference will follow up questions raised at Varna and its proceedings will be published by UNESCO under the title "New Trends in the Education of Teachers for Integrated Science".

The new concept in education needs a new educational technology. In September 1972 a Symposium on Educational Technology was sponsored jointly by the Committee and UNESCO. It was held in Paris and top scientists, experts on various aspects of this field were invited to discuss the following topics: the use of computers, television and radio; programmed instruction; audio-visual media and materials; integrated multi-media systems; educational technology in the training of science teachers. The symposium showed the promise and the limitations of the new trends in educational technology. The papers presented, together with the results of discussions, will form the basis of another UNESCO publication.

The Committee and UNESCO have supported and advised science teaching organisations in many parts of the world. They have helped to bring teachers together and to offer opportunities and advice to them as they attempt to prepare and to implement new curricula. It is hoped that this interest may lead to the creation of a World Federation of Science Teachers' Associations which will not only facilitate, on an international scale, the cooperation of teachers, but also cooperation between the teaching community and scientists. A number of representatives of science teachers' associations will attend the Maryland Conference in 1973 where the possibility of creating a federation will be discussed.

The activities enumerated do not cover all the interests of the I.C.S.U. Committee on the Teaching of Science. Its activity is much broader and can be summarised as follows:

(1) To further on an international scale progress in the teaching of science at all levels.
(2) To cooperate with other organisations concerned with any aspect of the teaching of science.
(3) To facilitate cooperation between Teaching Commissions of the International Scientific Unions.

REFERENCE

1 Inter-Union Commission on Science Teaching. *Congress on the Integration of Science Teaching Varna (Bulgaria) Sept. 1968.* C.I.E.S. 1968.

Articles Commissioned by Unesco to
Describe the Present Position and
Future Trends in Aspects of
Integrated Science Teaching
Throughout the World.

Chapter 1

AIMS AND OBJECTIVES OF INTEGRATED SCIENCE TEACHING

William C. Hall
Schools Council Integrated Science Project

Summary

Aims show teachers what the destination of the curriculum journey should be. In formulating aims at least four criteria should be borne in mind: (a) the all-round development of the pupil, (b) the 'consumer' requirements, (c) the nature of the subject, (d) feasibility constraints. To be useful in teaching, aims must be translated into specific objectives. These objectives can then be classified in a variety of ways; the classification chosen (i.e. the taxonomy) can then be used in assessment. There is an increasing interest in attitudinal aims in science education, which has important teaching and assessment implications.

1 The need for aims

> 'Would you tell me, please, which way I ought to go from here?'
> 'That depends a good deal on where you want to get to', said the Cat.
> 'I don't much care where ——' said Alice.
> 'Then it doesn't matter which way you go', said the Cat.
> '—— so long as I get *somewhere*', Alice added as an explanation.
> 'Oh, you're sure to do that', said the Cat, 'if you only walk long enough.'

It is all too easy to be like Alice in Wonderland when teaching science! The lack of clearly stated aims ensures that a scheme of work, instead of being an adequately sign-posted journey for the teacher, has the appearance of a mystery tour. (It is an exciting mystery tour with plenty to discover and lots of practical experience, no doubt, but nevertheless a mystery tour.)

This means that (for an examination subject) the aims of the scheme must be derived from previous examination papers. Alternatively, teachers must guess the scheme's aims from the way in which the course books have been written. Under such circumstances, teaching flexibility is difficult because hands are tied either by an externally imposed examination or by unsuitable text books, even though there might be a degree of freedom in selecting material from the texts.

Both situations ensure that it is not possible to answer adequately the pupil who asks, 'Why am I doing this?' and it is even more difficult to answer the question 'Why am I doing this in this particular way?'

The analogy of the journey can be usefully extended, as Figure 1 shows.

Journey	Curriculum development
What is the destination?	*Goals, aims and objectives
What vehicle is used?	Content (including processes and skills)
How do we drive the vehicle?	Teaching method
What maps are provided?	Publications; apparatus
How do we tell if we have reached the destination?	Evaluation and assessment
Who are our fellow travellers?	Other areas of the school curriculum
How do we tell others?	Training teachers

Figure 1 A journey compared with curriculum development

There is sometimes confusion between the terms goal, aim and objective. It is suggested that the progression should be goal – aim – objective.

There have been various models for the curriculum development journey and most of these have been based on the Tyler rationale [1]. More recent suggestions have tried to convert the Tyler model to a more dynamic statement. One of these, originally devised by Halliwell [2], is shown in Figure 2.

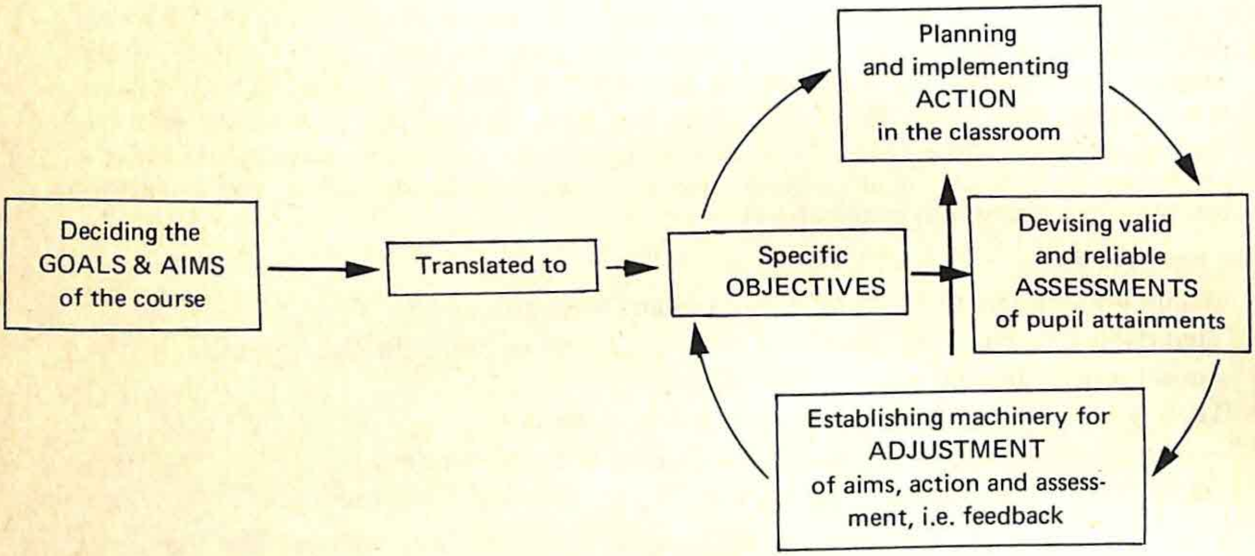
Deciding the GOALS & AIMS of the course
Translated to
Specific OBJECTIVES
Planning and implementing ACTION in the classroom
Devising valid and reliable ASSESSMENTS of pupil attainments
Establishing machinery for ADJUSTMENT of aims, action and assessment, i.e. feedback

Figure 2 The place of aims and objectives in curriculum development

This model implies that it is the *teacher* who is primarily concerned with all aspects of curriculum development including the formulating of aims. Curriculum development should not be something which is imposed from outside and it should certainly not be a 'package deal' to be adopted in its entirety: it is the teacher who makes the decisions. Also, the model assumes that the teacher in the classroom will take a major part in assessing pupil attainment, thus ensuring that the necessary (progressive) adjustments are made to aims, objectives and learning experiences. (This is in direct contrast to an assessment programme which is added to a scheme as an afterthought or to one which is rigidly planned in advance.) This interaction between aims and objectives, action, assessment and adjustment has been recognized by some of the recent integrated science projects. A good example of this is the Schools Council Integrated Science Project [3] where the original list of aims was modified as a result of assessment. Figure 3 shows both the original list and the modified list.

Aims, then, should be part of the whole process of curriculum development. They are not pious hopes written in the Preface of a book and forgotten; they are not merely part of an examination specification matrix; and they should most certainly not be carved into tablets of stone, thus remaining fixed for all time.

Original Aims		Revised Aims	
			Skills Pupils should be able to demonstrate their degree of competence in:
1A	To recall and to understand that information which would enable them to take A-level courses in biology, physics, chemistry or physical science, would enable them to follow a job in science or technology, would enable them to read popular scientific reporting and to communicate intelligibly with others on scientific matters, and would enable them to pursue science as a hobby.	1	(a) recalling and (b) understanding those concepts which would enable them to pursue science (courses in physics, chemistry, biology or physical science) to a higher level or as a hobby
		2	(a) recalling and (b) understanding those patterns which are of importance to the scientist.
2A	To understand the importance of patterns to the Scientist and to use those patterns in solving problems (both of a laboratory and of an every day type).	3	making critical appraisal of available information, from whatever source, as an aid to the formulation or extraction of patterns
		4	using patterns and making critical appraisal of available information in order (a) to solve scientific problems and (b) to make reasoned judgments
3C	To have the ability to organize and to formulate ideas in order to communicate to others, and as an aid to understanding, critical analysis, etc.	5	organizing and formulating ideas in order to communicate them to others
3A	To understand the relationship of science to technical, social and economic development, and to be appreciative of the limitations of science.	6	understanding the significance, including the limitations, of science in relation to technical, social and economic development
1B	To be honest in reporting scientific work.	7	being accurate in the reporting of scientific work.
2C	To be able to use resources (e.g. books, apparatus) at their disposal.	8	designing and performing simple experiments, in the laboratory and elsewhere, to solve specific problems and to show perserverance in these and other learning activities.
			Attitudes Pupils should:
1C	To work independently and as part of a group.	9	be willing to work (a) individually and (b) as part of a group
4B	To be willing to make some decisions on the balance of probability.	10	(a) be sceptical about suggested patterns yet (b) be willing to search for and to test for patterns
2B	To be concerned for the application of scientific knowledge for the good of the community.	11	be concerned for the application of scientific knowledge within the community
3B	To have an interest in science and technology and be willing to pursue this interest to higher levels.		

A aims: Knowledge B aims: Attitudes C aims: Skills

Figure 3 Original and modified lists of aims for the Schools Council Integrated Science Project.

2 How are aims selected

It is one thing to decide that aims are a necessary part of curriculum development; it is an entirely different matter to decide *which* aims are important. To assist in the formulating of aims at least four criteria should be borne in mind:

(a) the all-round development of the pupil (e.g. psychological development, social development, physical development and emotional development).
(b) a consideration of the 'consumer' requirements (e.g. further education, employers in industry or business, and the student himself);
(c) the nature of the subject (in this case integrated science);
(d) feasibility constraints imposed, for example, by resources, by the competency of teachers, and by the culture of the country.

It is easier to form quick opinions than to make balanced judgments, thus leading the over enthusiastic to ignore (a), (b) and (d). To ignore (a) ensures that pupils will not understand much of what is taught; if (b) is not taken into account the community as a whole will suffer; if (d) is not allowed for then the whole exercise can be a waste of time. Let us consider each of these criteria in turn:

(a) Psychological development

Approximate Age	
0-2 years	Sensorimotor period (e.g. walking, eating, crying)
2-7 years	Preoperational subperiod (e.g. acquisition of language)
7-11 years	Concrete operations (ability to reason in concrete situations)
11 → years	Formal operations (abstract reasoning)

Figure 4 A (much simplified) summary of Piaget's theories. It should be noted that there is no clear dividing line between periods and the ages stated are very approximate.

The work of educational psychologists should be taken into account when selecting course aims. For example, Piaget's theories [4] summarized in Figure 4 have influenced a number of integrated science schemes. Science teaching is organized in Scottish secondary schools as follows:

> 'Science teaching in secondary education is seen by us as a three stage organization, the first part of which is observational in nature, the second a more interpretive approach with some quantification of concepts, while the third is a generalization and further refinement of concept.' [5]

The Schools Council 5-13 Project [6] organizes its 'general objectives' (i.e. the aims) into three stages. Aims concerned with 'communicating' are shown in Figure 5.

Stage	Communicating Aims
Stage 1 Transition from intuition to concrete operations (Infants generally)	Ability to use new words appropriately Ability to record events in their sequences Ability to discuss and record impressions of living and non-living things in the environment
Concrete operations Early stage	Ability to tabulate information and use tables Use of representational symbols for recording information on charts
Stage 2 Concrete operations Later stage	Use of non-representational symbols in plans, charts, etc. Interpretation of observations in terms of trends and rates of change Use of histograms and other simple graphical forms for communicating data
Stage 3 Transition to Stage of Abstract Thinking	Selection of most appropriate graphical form to suit information Use of 3-dimensional models or graphs for recording results Deduction of information from graphs: from gradient, area, intercept

Figure 5 Communicating aims of the Schools Council 5/13 Project

Specific objectives derived from the Schools Council 5/13 Project aims which are concerned with 'the use of three-dimensional models' would, therefore, be inappropriate for pupils during stages 1 and 2 of their education in primary schools.

The more intelligent pupil is able to generalize by the age of about 13 years, and so one of the Schools Council Integrated Science Project's main aims is that its academically more able pupils should be able 'to search for patterns (i.e. generalizations) and to use patterns in problem-solving'. This scheme has been influenced by the Gagne learning hierarchy [7] viz:

1. Signal learning
2. Stimulus-response learning
3. Chaining
4. Verbal association
5. Multiple-discrimination learning
6. Concept learning
7. Principle learning
8. Problem solving

and has based its learning model on the last four stages (Figure 6).

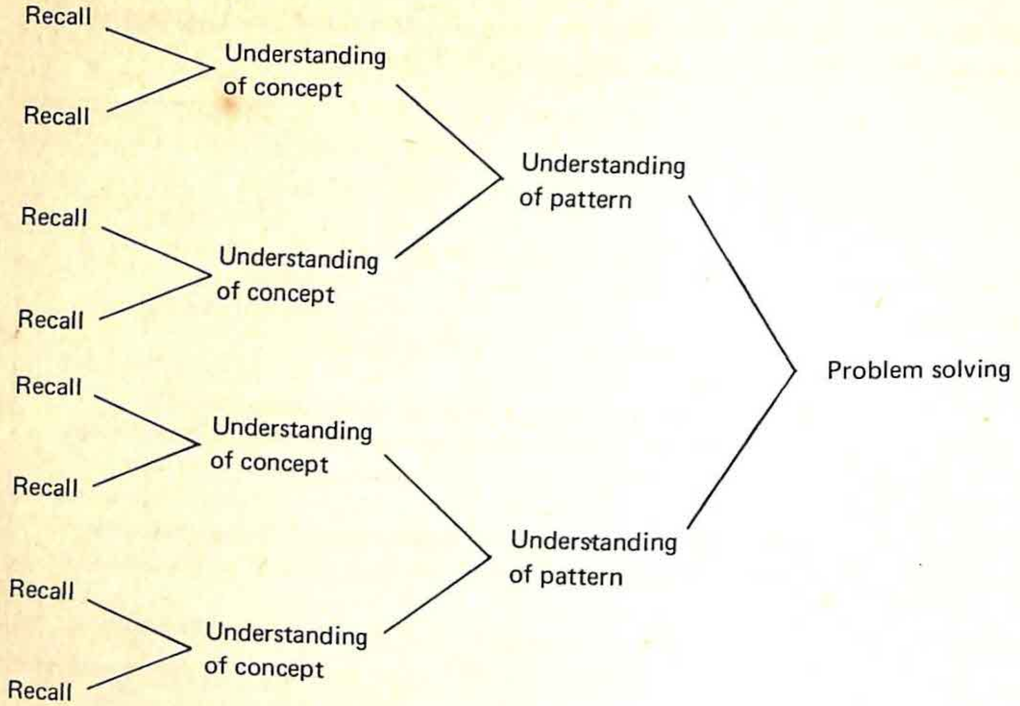

Figure 6 The SCISP learning model

Primary science projects, for example the African Primary Science Programme [8] and the Science Curriculum Improvement Study [9], generally recognize that aims based on first-hand experience and concrete reasoning are the most appropriate for this level of teaching. Examples of such aims, from the proposed curriculum and guide for the teaching of science in the infant schools of Barbados [10] are

> 'To arouse and broaden the interest of children in their total environment' and 'To develop an appreciation of the order and beauty of the universe and the world in which we live'.

Aims at this primary level of science education which are solely concerned with abstract reasoning would not be readily achieved.

(b) Consumer requirements

There is a world-wide movement towards the integration of the sciences. One reason for this is because employers are wanting more science-based generalists than single subject specialists. This is illustrated by the publishing of the McCarthy report [11] in the United Kingdom. It is important, therefore, that the aims of any integrated science scheme should reflect such a demand. Putting this another way, one must ask the question 'In what respects will integrated science aims differ from those of the separate sciences?' If the answer is, 'Not at all', one must be free to draw one's own conclusions about that particular scheme of work!

Aims such as 'To develop some understanding of man, his physical and biological environment, and his inter-personal relationships' and 'To develop some understanding of the nature, scope and limitations of science', both of which are included in the Australian Science Education Project [12], could not be achieved in any one single subject science course. Therefore they fulfil the necessary criterion outlined in the previous paragraph.

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An important consumer is the student himself. Few boys will study reaction kinetics in the kitchen after leaving a hard day's work at the factory, and few girls will perform (what scientists mean by) respiration experiments after a day at the office! However, many could be interested in science based hobbies such as collecting rocks, photography, electronics or gardening. Integrated science schemes should include aims which take account of this possible interest, as is done (for example) in the Nuffield Secondary Science Project [13] where 'significance' is defined as being 'aware of the everyday life of our pupils'.

The author has found the matrix shown in Figure 7 useful for selecting those aims which bear in mind the future 'consumers'.

	Knowing	Feeling	Doing
Job			
Family			x
Leisure	x		

Figure 7 Matrix for selecting aims

A family/doing aim might be 'to be able to mend electric fuses', and a leisure/knowing aim might be 'to know how to develop photographs'. It is suggested that secondary school courses in integrated science should consider including aims which are drawn from all nine areas of the matrix, although it is appreciated that the emphasis in different countries will not necessarily be the same and that deliberate ommissions might sometimes be made.

(c) The nature of the subject

Integrated science cannot achieve every aim in the school curriculum. (That is one reason why other subjects are taught at school!) However, science lessons are unique in offering particular ways of thinking and doing, and so some of the aims of an integrated science scheme should reflect this. The Science Teachers' Association of Nigeria [14] expands this 'thinking and doing' in detail in a statement on its course for the junior forms of Nigerian Secondary Schools:

'(i) *Observing* carefully and thoroughly.
(ii) *Reporting* completely and accurately what is observed.
(iii) *Organizing* information acquired by the above processes.
(iv) *Generalizing* on the basis of acquired information.
(v) *Predicting* as a result of these generalizations.
(vi) *Designing* experiments to check these predictions.
(vii) *Continuing the process* of inquiry when new data do not conform to predictions.'

Science–A Process Approach [15] is one of the more extreme schemes in its promoting of 'a way of thinking and a way of doing'. Its knowledge aims for primary grades are based on eight processes ranging from observing to recognizing number relations. At grades 4 and 5, six integrating processes are used in selecting aims: observing, using space/time relationships, using numbers, measuring, classifying and predicting. The other two processes, communicating and inferring are left for later years.

A number of integrated science schemes have adapted the taxonomies in Figure 8 for their requirements. For example, the plan for Scottish Education was considerably influenced by the Bloom cognitive taxonomy.

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If such a taxonomy is adopted four important principles should be recognized:

(a) So far there is no experimental evidence validating the Bloom (or any other) taxonomy.
(b) Independent judges often disagree when assigning objectives to various levels of a taxonomy.
(c) Objectives for teaching should be the same as objectives for assessment and both should be based on the particular taxonomy.
(d) Taxonomies are *man-made* and are intended to be useful *tools.*

When stated, (c) appears obvious, but it is all too easy to develop an assessment programme (with its hierarchy of objectives) in isolation from the teaching programme, and even recent integrated science schemes have sometimes been guilty of this. (d) is also important: the taxonomy readily becomes the master if care is not taken. In the same way that elements can be classified in a variety of ways (i.e. metals and non-metals; solid, liquid or gas; electrical conductor or non-conductor) so objectives can be classified in various ways. It is the most *useful* way which should be chosen.

Some of the most useful taxonomies are those which have been developed for a particular project. For example, the Schools Council Integrated Science Project classifies its knowledge objectives into one of four levels: recall, understanding concept, understanding pattern, problem-solving. An English examining board (The Associated Examining Board) for its Physical Science syllabus [19] has the following list of abilities:

Knowledge
Practical technique
Routine problem solving
Novel problem solving
Evaluation

The Irish Science Curriculum Inovation Study (ISCIP) [20] in the Republic of Ireland classifies its objectives under the general headings:

Behavioural skills
Knowledge of facts and concepts
Awareness

During the past decade there has been a growing interest in objectives in the 'feeling' and 'doing' areas of science teaching. This is reflected in the aims of the UNESCO programme in integrated science teaching [21]: 'The UNESCO programme should aim to assist the Member States of UNESCO to stimulate and strengthen the scientific attitudes and skills of children . . . . .'. This was expressed in practical terms by the Ghana Association of Science Teachers [22] as follows:

> 'The choise of objectives for secondary school science education should depend on the needs of the country and on the cultural background of the students. In general terms, Ghana requires honest, resourceful citizens with well-developed critical faculties. They should look upon innovation as the basis of progress and have confidence in their own abilities for independent inquiry and action towards practical ends. Science education should enable a person to operate effectively in three areas: in the family, in the community and in his chosen occupation. He should be well-equipped with the attitudes and basic knowledge necessary for the understanding of and effective participation in the social, agricultural, and technological development of the country. Critical faculties and knowledge developed in the study of science should be applicable to a wide range of situations encountered in everyday life, as well as to the study of other areas of learning. These general statements imply that the development of certain attitudes is at least as important as the acquisition of factual knowledge and manipulative skills.'

(d) Feasibility Constraints

If little money is available for curriculum development in a country, there is no point in including aims which can only be achieved by purchasing expensive apparatus. This (rather obvious) statement has particular bearing when one country is considering importing and adapting another country's science scheme. Curriculum developers must face up to harsh realities! However, it is hoped that teachers will always be allowed to formulate their own aims, and that aims will not be imposed by some external agency whose sole concern is economic constraint. The competency of teachers must also be borne in mind so that (if necessary) in-service training programmes can be devised. However, if the curriculum changes take place from within (as distinct from being imposed from without) many of the earlier curriculum development problems experienced by some countries will not arise.

3 Aims into objectives

Aims are always general and diffuse; for teaching purposes they must be translated into specific objectives, preferably behavioural so that assessment is possible. (It will be recognized, however, that the achievement of some objectives cannot be measured at school: they are long-term but are just as important and should not be neglected.) An objective is useful if it shows what changes are expected in a student as a result of a particular learning experience. For example, the General Science scheme produced by the Aiyetoro Comprehensive School, Nigeria [16] has the following objectives (in the form of questions) for an observational activity using a leaf:

'Do the pupils:

(a) examine the leaves carefully: edges, tips, both surfaces, leaf-stalk, mid-rib, veins, etc?

(b) use good oral and written English to describe a leaf?

(c) seek new terms in English for observed properties of leaves?'

From even a few general aims it is possible to write a long list of objectives. Fortunately these objectives can be classified into groups, and various taxonomies (i.e. 'orderly arrangements') of objectives have been proposed. The most popular are the taxonomies suggested by Bloom et al [17]. Aims are first broadly classified as cognitive ('knowing'), affective ('feeling'), or psychomotor ('doing'). These broad classifications are then subdivided into further groups as Figure 8 shows.

Cognitive	Affective	Psychomotor
Knowledge	Receiving	Initiatory level
Comprehension	Responding	Pre-routine level
Application	Valuing	Routinized level
Analysis	Organization	
Synthesis	Characterization	
Evaluation		

Figure 8 Various levels of classifying objectives.

This particular psychomotor classification was suggested by the Ceylon Ministry of Education [18]. It is somewhat restricted and it is suggested that process skills might also be included (e.g. the 'searching for patterns' of the Schools Council Integrated Science Project). An example of a cognitive objective would be 'To know how to connect up a Wheatstone's bridge circuit'. An affective objective would be 'To be excited at the prospect of connecting up a Wheatstone's bridge circuit'. A psychomotor objective would be 'To be able to connect up a Wheatstone's bridge circuit'. (The reader will appreciate the extreme hypothetical nature of these objectives!)

It is also being recognized by teachers that the impact of science and technology on society should be investigated in science schemes. Layton [23] has expressed it in this way:

> 'Today the social environment of science has been transformed, just as science itself has grown from 'little' to 'big science'. Science and technology are now inextricably interwoven into the economic, political and ethical problems of our time. Also, as a direct consequence of its own growth, science has become increasingly dependent on state patronage, with a demand far in excess of the resources available. In consequence, and in a short space of years, science has moved into a position where it is a public activity of major importance. Decisions have to be taken in planning for the national development of science and technology, and because of their significance these decisions need to be taken publicly and with social consent. They entail a scientifically literate population. Science now has to be as directly accountable to its supporting public as any other activity of similar social influence. From being an instrument of public policy—an agent which was available for use in the achievement of agreed social objectives—science has now become itself an object of public policy.'

In short, one of the things which is being suggested here is that science is a humanity.

Integrated science can best provide the broad coverage necessary to achieve the type of aim stated by the Australian Science Education Project which reflects the science/technology/society interaction: 'To develop some understanding of, and concern for, the consequences of science and technology'. This is because the social implications and technological applications of science generally have reference to all areas of science and not just to, say, chemistry or physics. For example, one of the consequences of technology was to cause people to work in factories and to live in towns, which led to the creation of slums like those shown in Figures 9(a) and (b). A discussion of living conditions thus becomes a natural part of any treatment of machines in an integrated science scheme.

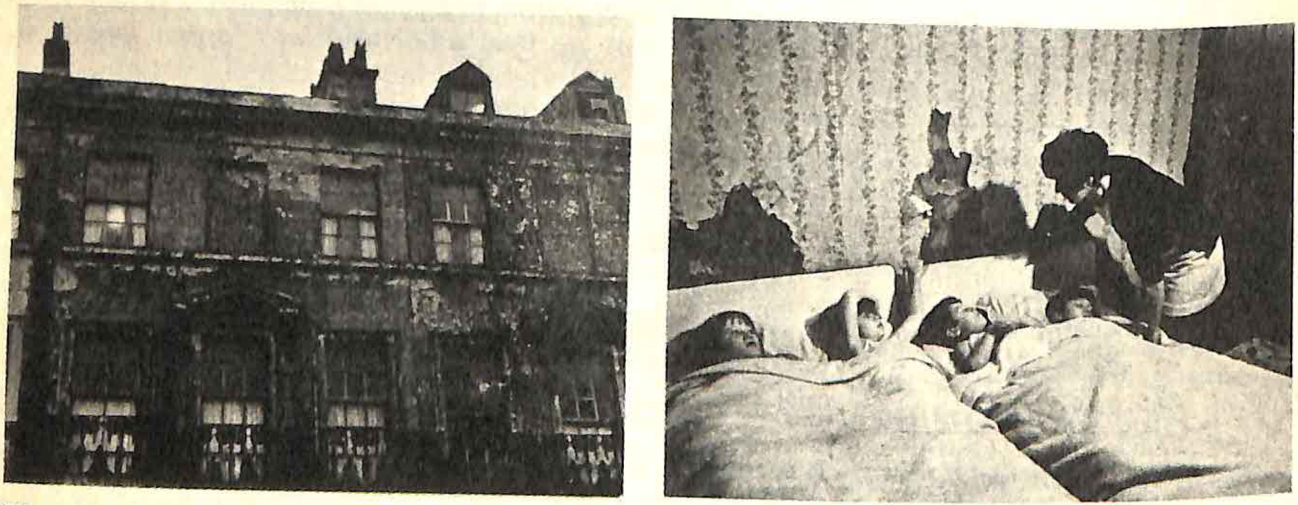

Figure 9(a) (b) Slum property (courtesy of 'Shelter')

Science teachers concerned with the all-round education of their pupils will welcome both of these new emphases. They will also welcome the move to integrate science teaching into the whole curriculum.

4 Some implications of an objective based scheme

Hilda Taba in her book 'Curriculum Development–Theory and Practice' [24] suggests that 'The learning experience, and not the content as such are the means for achieving all objectives besides those of knowledge and understanding'. Even a glance at the general aims, or the grouping of specific objectives, of most integrated science schemes shows that there is a concern to achieve objectives additional to those which are primarily 'knowledge' or 'understanding'. Examples of this were given in the previous section and a further example is to be found in the report of a sub-regional conference on curriculum development held at the School of Education, University of South Pacific [25], which states:

> 'Specific objectives of science teaching have been listed many times by many people. They may differ slightly from one list to another, but almost all come under the six essential components of general education, namely: decision making, truth seeking, skills of living, communicating, adapting to change, and aesthetic awareness.'

Although all of these six components require a degree of 'knowledge' and 'understanding', objectives based on the components will not be achieved merely by emphasizing the content of a scheme. They will only be achieved by undergoing particular 'learning experiences'. (Similar illustrations can be found in other integrated science schemes.) The first implication for an objectives based integrated science theme, therefore, is that it is impossible to achieve new objectives by teaching old content (e.g. an amalgam of physics + chemistry + biology) in the old way. Particular learning experiences must be devised if the 'heart' and the 'hand' as well as the 'head' are to be influenced.

The second implication is that new ways of assessing objective achievement must be devised. There is little point in listing objectives for which there is an inadequate assessment programme or, to use the journey analogy, as well as knowing what the destination is supposed to be, it is also reasonable to demand some indication of when the destination has been reached! Otherwise the mystery tour will run true to form, and the people on the journey will eventually arrive back at the starting point again, happy and tired but having achieved little. This happened to Alice, much to her relief; science teachers and pupils will not be so readily satisfied!

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Shapes for children; shapes for teachers

Chapter 2

TOWARDS A RATIONALE FOR INTEGRATED SCIENCE TEACHING

Abraham Blum
Agriculture as Environmental Science Project

Summary

The reasons for the growing trend in integration in science teaching and the arguments in its favour are discussed. The need to look at science education as part of development in general is stressed. Some implications for teacher training are mentioned.

The question: "Are the structures of the disciplines a help or a hindrance in integrated science teaching?" is then dealt with and the differences between *Integrated Science* teaching and *Integrated* science *Teaching* are discussed. The special place of mathematics and of elements from the humanities and social studies in integrated science teaching are reviewed. The author advocates a stronger link between basic and applied sciences, and between applied science, technology and decision making. Many examples are cited from various curricula, which have started to go in this direction, and a unit of the Agriculture as Environmental Science project is introduced.

Finally an Integration Matrix is proposed, which can be used to show graphically where projects stand in regard to the main dimensions of integration: the scope of subjects covered and the intensity of integration are shown and the environmental involvement is considered.

Clarification of the "labels" used in science curriculum reform is essential and the author expresses the hopes that with the accumulation of experience, a more comprehensive rationale for integrated science teaching will be formulated, which will help to plan effective and well adapted programmes.

1. INTEGRATION–A GROWING TREND IN SCIENCE EDUCATION

In recent years the interest in integrated science teaching is growing rapidly, as is the trend towards increased integration in education generally. Both scientists and educators, who were trained in specific disciplines, have now joined forces in order to find ways and means of achieving the long sought-after goal of unity. They seek to bridge the gap between the sophisticated methods of research of the scientist and the child's concept of his environment.

During the past five years many more integrated-science curricula and integrated systems of science teaching were developed than in the previous decade of curriculum renaissance starting in the late 1950's. All over the world teams work on the development and the improvement of programmes in integrated science teaching and ask themselves "Can and should we integrate–what and how?"

Therefore a rationale for integrated science teaching is needed. Teachers, scientists, educational administrators and curriculum specialists are looking for guidelines, to assist in the planning of effective science teaching programmes, geared to the needs of their students. They will have to take into consideration philosophical, psychological, pedagogical and practical arguments both in favour of integration and against it. They will have to decide how far to go in the integration process, which topics to choose and how to fuse all these elements together.

Integrated science is a growing trend. Each new project adds new ideas and over the course of time a more generalizable rationale can be formulated. This chapter is thus only a first step on a long road.

The Search for Unity

The search for unifying principles is as old as mankind. Ancient natural philosophers such as Aristotle [1] and many scientists including Einstein [2,3] believed in the unity of the universe and tried to discover the unifying laws of nature. Even when separate scientific disciplines developed, each concerned with different levels of organization and, as a result using different methods of research, philosophers and creative scientists were conscious of the danger, which lies in narrow specialization.

Auguste Comte [4] built a hierarchy of disciplines and showed that each discipline is based on a more fundamental one. Schwab [5], reinterpreting this model, argued that in scientific inquiry we do not hesitate to go from one discipline to a more basic one, when the investigation of a problem demands it. Malek [6] points out, that–

> "In the development of science, the frontiers of the various disciplines are in constant and continuous movement; new boundary–disciplines arise, which at the time of their emergence are interdisciplinary, but which are gradually established as new disciplines (e.g. biochemistry, biophysics, physical chemistry, bionics, bio-engineering). Even when they are fully established as individual disciplines, their teaching needs to be very much of an interdisciplinary nature to enable the new discipline to develop further".

Progress in research accelerated when creative scientists began to use the way of thinking and methods of one discipline, or of a few combined, to investigate problems in another field. Specialisation has often been a hindrance by leading the inquirer into a narrow approach, which did not lead him to a satisfactory solution [7]. In many of these situations a team of scientists from different disciplines could have overcome the difficulty. A quick glance through some of the major scientific journals shows that today most research is done by teams which are more often than not made up of scientists with special knowledge and skills in their respective narrow fields, but who can communicate and interact creatively with members of other disciplines. They must be able to see their limitations and how these can be overcome by creating new connections between different subjects and methods. Integrated science teaching can help to educate students to look at a field of study not only from within but also from the viewpoint of links between disciplines.

Psychological and Pedagogical Arguments

There is no concensus of opinion among learning psychologists about the extent of transfer of training from one field to another. Many, like Bruner [8,9], are optimistic and believe that one can have massive transfer of concepts, principles and strategies from one learning situation to another–within the same discipline as well as between subjects. Other learning psychologists, like Gagné [10] (and Thorndike before him) [11] acknowledge only limited transfer, and only then when a learned concept or principle can be directly employed in a new situation. Ausubel [12] maintains an intermediate position. It would be useful to know how far transfer is influenced by the narrowness of the learning situation. It is quite possible that an integrated approach to science teaching might enhance transfer of training, by giving the student more occasions to use the concepts and principles learned in one discipline in a not too distant field–such as an applied science (e.g. the use of biological principles in agriculture, or in nutrition). [13,14]

A child and even an adult does not learn in the same logical order as that in which a scientific discipline is organized. [15] For teaching purposes we have to take into account the psychology of the student and the ways in which he forms concepts. [16] The structures of acquiring, assimilating and retaining knowledge are the same, whether we learn biology, chemistry or physics. Many concepts and the fundamental attitudes towards science are not restricted by discipline boundaries.

We start science teaching usually in the elementary school, when children are in their concrete stage of development, according to Piaget. [17,18,19] They are then mainly concerned with sensing and manipulating concrete phenomena, and the theoretical structures of the various disciplines are still outside their grasp. Therefore rather than speak of integrated science teaching at the elementary level, the term *undifferentiated* would be more appropriate. [20] The young, curious mind does not differentiate between subject matter fields when it seeks to find out about its environment. The problems it encounters are interdisciplinary and the discoveries made are integrated with the whole outlook of the child. Science should be taught, writes Chief Awokoya [21] "as a whole as it affects the child in the totality of his environment."

In science education one should concern oneself not only with the transmission of knowledge, but also—and perhaps mainly—with the training of a critical mind and the fostering of scientific attitudes such as the readiness to use one's judgement in a critical review of data [22,23,24] Since these attitudes are as important for work as for leisure activities a wide range of topics should be chosen to demonstrate how science and scientific thought influence our lives. [25] A narrow disciplinary approach could easily create the impression in students, that scientific attitudes are valid only when dealing with a relatively small range of problems, mainly those concerned with research in science, while an integrated approach, which would include problems from different areas in life, could stress the growing interdependence between science and society.

The Needs of Society and Integrated Science Teaching

Schwab [26] writes about the growing role of science in society:

> "Industrial democracy has made science the foundation of national power and productivity. Science now plays the part once played by exploration, by empire and by colonial exploitation. It is this change in social role, which has changed the pattern of scientific enquiry."

Therefore not only should the scientist understand the relationships between science and society, but also the public, who will have to decide major issues involving science and society. Hence science teachers cannot absolve themselves from the need to integrate social elements in their curriculum.

As has happened often before in education, some writers start from the point of view of society, as does Schwab [27] who writes:

> "In happier and more peaceful times there might be arguments stemming from the consideration of the individual's happiness and satisfaction. In our times, however, the reasons which are most urgent and compelling, stem from the milieu. They are matters concerning our welfare as a polity".

Science is more and more becoming a powerful tool in the development of nations. Its concentration in the hands of the technologically advanced countries will widen the gap between the developed nations and those, which have only now a chance to advance. Development is a complex process and science is part of it. But science becomes relevant to development only when people realize its importance to their life and develop positive attitudes towards science as a developmental tool.

Major conferences on rural development, such as the Commonwealth Conference on Education in Rural Areas [28] and Unesco Workshops in Asia [29], Africa [30], and the Pacific area [31] have stressed the point that integrated science teaching which relates to development problems, can make a major contribution towards development itself. So far science teaching programmes have not yet realized their full potential in the developmental process. Integrated science teaching can and should treat interactions between scientific research and the agricultural, technological and social problems, which arise in the developing village, the growing city and the emerging nation. Then science teaching will become a more powerful factor in education towards development. For this reason a wider cooperation between science teachers and other developmental agencies is needed.

Integrated science teaching is a good starting point. It takes inherently a wider view of what science is and can do. Therefore integrated science curricula can serve as part of a coordinated development plan more easily than segregated science courses, which are built round the historical structure of the disciplines.

Adjustment to Change

Our whole environment changes under the impact of science and we, as individuals, will have to adjust ourselves to changing conditions. On the one side the emphasis on the common factors of science and less specialisation might lead to a better adaptability to change. On the other side modern man is puzzled by the quick changes and tries to understand the changed picture of the world.

> "Interdisciplinary science", writes Malek [32] "corresponds to the necessity of present (and still more, future) society to educate harmonically well balanced human beings: each of the disciplines in its connection with others, contributes to this harmony."

Here again then, we hear the echo of the age-old yearning for harmony, not unexpected from a scientist. Perhaps the scientist, more than other professionals, can grasp the stress of the growing complexity of modern life and tries to overcome this stress by reorganizing his Weltanschauung in a more integrated pattern.

Practical Reasons

Finally practical reasons have often been behind the creation of integrated and combined science courses. In many countries the examination system has a strong influence on what is taught in school, and three separate science courses would take too big a share of the time table. As a result integrated science courses were found to be a better solution than forcing the student to choose one or two of these courses, thereby forfeiting the possibility of studying, at least to some extent, the whole range of science.

General Science and Integrated Science

It is impossible, in the light of the avalanche-like accumulation of knowledge, to return to the ideal of the Renaissance man—the all-round-scholar. Even a genius can no longer comprehend the vast amount of knowledge contained in science. Should we, therefore, try to restrict teaching in school to the intensive treatment of an isolated discipline or should the students tackle selected chapters, chosen from different fields? Should we return to the ill-famed General Science course, to teaching a bit of everything?

Not that the idea of general science, as it developed in the 1930's, was a bad one. Actually many science educators who advocated general science were prompted by the same arguments as those put forward by the promoters of integrated science. Yet in practice many general science programmes failed—and integrated science teachers should learn a lesson from the failure. Usually general science courses consisted of a mixture of chapters from the classical disciplines of natural science and did not show the interconnections between these disciplines. And without the emphasis on the whole, the parts lose much of their value.

In many cases general science was considered to be a suitable course for less able students. The intellectual demands were lowered, the subject matter content was watered down, the approach was often superficially descriptive and seldom quantitative. Again: these are not necessarily characteristics of general science teaching, but since they were observed so often, they helped to give general science a negative image. General science courses, as well as segregated science courses at that time, focused on the knowledge about the end product of scientific research rather than on the method of scientific inquiry, the process of formulating and verifying hypotheses. Integrated science programs are influenced by the developments which have revolutionized science teaching in the last ten to twenty years.

Teacher Training for Integrated Science*

Perhaps the biggest drawback of general science was that the teachers were not trained to teach topics culled from vast areas of science in depth and as a result their teaching often become trivial. Modern integrated science projects realize this difficulty and try to retrain the teacher through courses, extensive teacher guides and manuals, and suggestions for cooperative methods such as team teaching.

If integrated science teaching is to succeed, we shall have to introduce changes in the training of teachers. More emphasis must be given to the investigation of integrated issues, problems and techniques of interdisciplinary research and decision making. The study of relevant problems from the philosophy of science, which show the universal character of science and its relationship to other aspects of life, will help to foster teachers' positive attitudes towards integrated science.

2. INTEGRATED SCIENCE AND THE STRUCTURE OF THE DISCIPLINES

The new science teaching curricula, both the discipline-centered and the interdisciplinary types, have stressed the paramount importance of structure in science. Some stress the need to understand conceptual schemes, others emphasize the processes, the ways of collecting and using evidence. But all agree that science is not merely a collection of facts, which grows by accretion, but a building in which the bricks of knowledge would fall apart without the cement which holds them together. Furthermore, in the light of the "knowledge explosion" and faced with the problem of what to teach in the limited time alloted to science education in school, a review of the situation has shown that structures change much more slowly than factual knowledge and therefore are more likely to be of use, when today's students become adults.

Though based on many common, fundamental ideas, processes and attitudes, scientific disciplines, both classical and emerging, also have their own structures, differing in varying degree from one discipline to another. Therefore we have to give an answer to the question: Is integrated science teaching not neglecting the need to teach the structures of the disciplines, as postulated by philosophers of science? [33,34,35,36] In answering this question, we shall differentiate between the structures of the disciplines, as seen by the philosopher of science, and the educational goals, which we want to achieve through science teaching. In the first case the emphasis will be on *Integrated Science* teaching, in the second case on *Integrated* science *Teaching.*

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*In this section no attempt is made to discuss the problems of training integrated science teachers. These will be the subject of a forthcoming congress, the proceedings of which will be published. Here we only wish to draw attention to one of the central and critical problems, which integrated science teaching will have to solve.

Our first step will be to try and identify the clusters of disciplines which organize knowledge according to subject matter and to determine the relationship of these disciplines to one another. Insight into this relationship will help us to determine what may be joined together for the purposes of teaching and what should be held apart. Our starting point will be Aristotle's classification of the disciplines [37,38]—a very old but still very useful guide, as we shall see.

Aristotle discriminates three classes of disciplines: the theoretical, the practical and the productive. The *theoretical* disciplines are those whose aim is *to know*—mainly mathematics and the natural sciences. [39] The *practical* disciplines are quite different. Their aim is to do, to choose deliberately between given alternatives, *to decide on an appropriate action.* Although Aristotle includes in this category mainly ethics and politics, we could add modern applied sciences like administration, systems theory and perhaps those parts of medical, engineering and agricultural sciences which are concerned with what should be done in a certain situation, based on "theoretical" (e.g. "scientific" in the narrow sense), economic and moral considerations. The other parts of engineering and agriculture together with the fine and the applied arts belong, according to Aristotelian division, to the *productive* disciplines.

Schools have too often overlooked the second and third of these classes. They have treated all disciplines, including science, as if they were only theoretical. Teachers and curriculum planners in integrated science education will have to take a stand on this issue. They will have to answer the question: How far can and should we integrate theoretical, practical and productive elements of science, or in modernized terms: How far can and should we interweave elements from pure science with others from applied science and technology?

The classical disciplines of science—mathematics, physics, chemistry and biology (and to many: sociology) differ not only in the degree of precision to which they can be investigated. Comte [40] for instance argued that each of these disciplines concerns itself with a given "order" of phenomena. Each order consists of members of the next lower order organized into more complex structures, e.g. biological organisms consist of chemicals (the next lower order) and chemicals of physical elements.

If we accept this view, we must assume that no biology teaching is complete without some study of chemistry and that to understand chemistry one has to study physical phenomena and laws. But since we cannot postpone the study of biology until the student has mastered chemistry (and before that—physics and mathematics), we have to use elements from one science, whenever they are needed to understand a problem arising from the study of another science.

One of the things which integrated science teaching tries to do, is to interconnect the sciences, where the need for such a connection arises. Where useful, subject matter elements, concepts, methods of research can be borrowed from another discipline without blurring the different structures, which are typical for each discipline. Actually, this interplay between disciplines, has been most fruitful in giving science its revolutionary structure. [41] New disciplines emerged and go on doing so. Some are intermediate steps between classical disciplines: mathematical and chemical physics, biochemistry, ethology. Others like bioengineering and electronics connect horizontally between science and technology.

The Special Place of Mathematics

Because mathematics is classified together with the natural sciences, it has often been taught as if numbers and figures were abstractions from experience with real, natural things. Its unique character is often overlooked or pushed aside. Mathematics derives from the invention of logical forms which are outside our power of observation, and is based on arbitrarily chosen axioms and sets of rules. [42] New Mathematics teaching stresses this difference in fundamental structure. The special structure of mathematics is also often distorted by treating arithmetic, algebra and geometry as separate subjects. For this reason the Russian Academy of Pedagogical Sciences recently developed mixed problems in the study of arithmetic, algebra and analytical geometry in secondary schools, in order to create a united and harmonious system. [43]

In spite of its special place among the sciences, mathematics can play an important role in integrated science: mathematics is the discipline which abstracts and codifies the structures which other disciplines have invented and tested. It enables the creation of models, with the help of which scientists in other disciplines search for new structures and insights. Mathematics is a language and as such serves to organize thought and to express generalisations in numerical, symbolic and graphical form in all natural and most social sciences. As a language, mathematics is a basic skill, which should be used in integrated science teaching (subject to pedagogical limitations).

Applied Science and Decision Making in Integrated Science

So far we have concerned ourselves with the integration of disciplines and mathematics. Now we shall come back to the relation between theoretical, practical and productive disciplines (in the Aristotelian scheme) and add to the "pure" or basic sciences, which have occupied our attention so far, the "applied" sciences and technologies.

Applied sciences explain characteristics and properties of man made devices and systems (e.g. engineering science) or explain what happens when Man interferes in nature (in agriculture, medicine or education). All these applied sciences use the knowledge acquired and the methods used in more basic sciences (e.g. biology in agricultural science, chemistry in pharmaceutical science, physics in engineering science). They search for answers to the question: "*What can* be done?" The applied sciences are closely connected with their corresponding technologies: agriculture, medicine, engineering and teaching, which tell us *how* something can be done. But between these two questions–What can be done and how?–there is another one, which is often overlooked or pushed aside: *"Should* it be done?

We often have the applied knowledge that something can be done (under given circumstances) and we know what happens if we do it. We even have the technological know-how–but we still have to decide on the action. This decision making process should be added to the teaching of the applied sciences and their technologies. Decision making–unlike applied science and technology is not only based on factual knowledge, but also on motives and value judgements. Examples of decision making can be found everywhere. Medical science can tell us that a certain operation (given the technological know-how and facilities) can be done and that the patient's chances of living are, say, 50%. The doctors have still to decide in every case, if and when to operate. Civil engineers, working together with biologists can suggest three alternatives for a sewage plant. Which should the city fathers choose–the cheapest, that which can be built quickly or that with the lowest pollution hazards? Educational research findings can tell a teacher that a certain type of film on the reproduction of man is suitable for ten year olds. Should the teacher show the film, if the parents object?

In all these cases somebody has to make a decision. Decision makers need skills, which are different from those of the basic scientists. The scientist often chooses a problem to fit his techniques. The decision maker, confronted with a complex problem, has to evaluate which among a multitude of possible observations and techniques is relevant to his problem, and he has to decide, often on the spot, what to do.

Aristotle has called the developed competence to exercise this judgement—practical wisdom. Until lately it was hoped that this wisdom would accrue from experience, through apprenticeship and internship. [44] Decision making was not taught in schools. Andrew [45] argues:

> "Just as the curricular reform groups of the 1960's criticized the 'traditional curricula' for neglecting the creative processes of scientific inquiry, so too have most of the recent curricula neglected the processes of application of scientific knowledge, the technology that results from these processes and the interactions of technology and human life."

Foecke [46] writes:

> "It would be extremely beneficial if education for decision making were a much more explicit and visible part of our educational programmes. Indeed, because the ordinary man in the street *applies* knowledge . . much more often than he *generates* it, it would seem that the decision making method should receive as much attention as the scientific method."

In spite of the progress made in cybernetics and systems analysis, we know little about how the best minds come to decisions. Outstanding diagnosticians and chess-players often seem to proceed "intuitively" rather than by a carefully built analytical system. But we can teach the principle of alternatives of action, of options, of which factors to consider. We can discuss and simulate real life problems in school. With the growing concern about environmental issues, about the world food problem and population explosion, some science teaching programmes have started to integrate problem solving and its techniques into the curriculum.

Various curriculum projects, like the Educational Research Council's (ERC) Science Programme [47] in the U.S. and Schools Council Integrated Science Project [48] in Britain have developed simulation games to pose a problem which the participants in the game are asked to solve. In other projects, like the "Agriculture as Environmental Science" [49] project in Israel, students are confronted with protocols of debates and public hearings and are asked to make a reasoned decision. They also receive contradictory expert opinions on pesticide pollution and have to appraise them critically.

The "Foundational Approach to Science Teaching" (FAST) [50] in Hawaii connects its two main strands, the physical and the ecological, with a relational strand, which starts with a unit on decision theory. The Australian Science Education Project [51] focuses on the stage leading up to decision making: the understanding of man himself, his function as an individual and as a member of a group, his ability to learn from the environment with the help of devices which he invented and, last but not least, the understanding of man's impact upon the natural environment.

The learning about man's devices, which was often left to the arts and crafts, is more and more integrated into science teaching—and vice cersa. In France the recently revised subject "manual work", according to the guidelines of 1960 now resemble closely the objectives of traveaux scientifiques experimentales, with subjects like "climate and man", "forest and man", but also "the motor", "the bicycle" [52]. Manual work, according to the 1960 guidelines ". . should train not only the manual skills in the narrower sense, but also the mind in general, observation, imagination, inventive spirit, judgement, taste".

Garden work, in conjunction with biology learning is included in the comprehensive program for both Berlin and Northrhine—Westphalia, in Germany [53], and also in Africa. [54]

Many important curriculum projects, which in the past were strongly discipline minded, started to integrate social studies and problems from the environment into their new programmes, BSCS [55] recommends a socially involved middle school programme. The Nuffield Foundation's work, which started with separate courses in physics, chemistry and biology, concentrates increasingly on combined science. [56]

Science teachers in the developing world strongly feel the need to give education towards planned action. Regional workshops in Bangkok, [57,58] Ibadan, [59] Nairobi, [60] and Fiji, [61] have, in their reports, stated a strong preference for integrated science, which would include applied sciences and problem solving. A science project in Papua/New Guinea [62] includes health science—a problem area integrated into many science programmes, specially in developing countries.

Major conferences on education and rural development have stressed the need to develop rural and environmental science programmes, which should be integrated into a school wide effort to educate towards attitudes needed for rural development. [63,64,65,66,67] Many of the developing nations are implementing this recommendation, mainly through integrated science teaching. The biology text of the School Science Project (East Africa) [68] includes extensive chapters on health and agriculture as applied science.

In the lessons prepared by the Institut Pedagogique Africain et Malagache [69] about a quarter of the activities are on agricultural practices and crops. South Americas FUNBEC [70] deals with the use of electricity, healthy living and food production. "Let's Grow Plants" [71] the first part of the Agriculture as Environmental Project in Israel, treats agriculture both as applied science and technology. Mauritius is introducing a science course, into senior primary schools based upon the local environment and a practical approach, and Zambia has a new science programme centered on agricultural science. [72] In the South Pacific, crafts are part of environmental science. [73]

Agriculture as Environmental Science

When we consider applied science as a necessary part of an integrated science approach, we have to develop suitable techniques. Fundamentals of modern science teaching like discovery learning and open-ended experimentation will, of course, be the basis of such a curriculum. But more specific elements will be added. Field experiments will then be planned, on problems which are both of interest and value to the student and important for the country's development. Original or specially adapted professional literature will be used to let the student learn how and where to acquire more information in the future.

The Agriculture as Environmental Science [74] project in Israel has developed such a curriculum, which is part of a highly coordinated science programme. The 7th grade course of the project, "Let's Grow Plants" [75] for instance, includes the theme "Regulating the Time of Flowering". It is typical of the applied and environmental approach to integrated science teaching and is included as an example in Part 2 of this book.

The theme "Regulating the Time of Flowering" was chosen as a positive example of Man's endeavour to use science and technology (agriculture) in order to "manipulate" nature for his own purposes. It is also of considerable economic importance for the country's expanding export of flowers, based on the scientific use of natural factors. Both aspects can help the students to come to the conclusion, that scientific agriculture is an important part of rural development for the individual, the village and the whole country.

Field experiments, in which agricultural plants and their living conditions are manipulated, have also a twofold appeal to students. Evaluation reports [76] have shown that students express the feeling that they have "a certain control over nature". This thrill was so strong, that the students ranked experiments like the one described, and grafting experiments (which some compared to heart transplantations) consistently higher in interest than the more common germination experiments—although the latter give quicker results.

Finally flower growing has also a strong emotional appeal to many students and can lead to a life long hobby.

Technology and Integrated Science

In more industrialized countries some projects have started to develop materials, which integrate elements of science and engineering. Project Technology [77], in Britain, prepared technical descriptions of quite sophisticated equipment and experiments. The Engineering Concepts Curriculum Project [78], in the USA, produced "Man Made World", using a systems approach to the solution of problems. Engineering, like agriculture, will in future make a much more meaningful contribution to relevant, integrated science teaching than so far.

The Humanities and Integrated Science Teaching

Since the reform in science curricula started some 15 years ago, there have always been voices calling for a closer link between science education and the humanities, but their influence has not been overly conspicious. Schwab [79] stressed the importance of teaching the structures of scientific research and of relating development of scientific ideas to their philosophical background.

Klopfer [80] and Cohen [81] used the history of science to improve the image of science and of scientists, as conceived by science students. Klopfer [82] advocated special courses in scientific literacy—for non-science majors. Eisner urged the use of cognitive and affective elements, and also that students should be given a chance to express themselves creatively; Newman [83] urged the exploration of interconnections between the sciences and the arts. Only recently have science curricula integrated elements from the humanities to any extent. Harvard Project Physics [84] could show, that by doing so the negative image of the scientist as a human being could be changed. [85] The Iowa Science and Culture Study [86] developed units on "science and culture", "science and politics in antiquity: the philosophical dimension" and on the "scientific revolution of the 16th and 17th centuries."

The growing recognition among science educators, that the relations between science and the humanities should be treated in integrated science education is mirrored in science teaching journals, which now seem to publish more articles on this problem than they did ten years ago. [87,88,89] The "Idea-Centered Laboratory Science" project [90] calls a unit "A scientist finds that his world has limits" and hints at a problem often overlooked: communication. Science teaching texts pay much attention to the exact definition of terms and accurate explanations of concepts. But usually they do so only within the context of their own discipline. So the students learn about "factors" in mathematics, in the natural and social sciences—and no coordinated effort is made to explain, that the connotation changes in each different context. Here too a vast field of integration is still lying fallow, and only few science teaching projects have explored the possibilities: The Schools Council Integrated Science Project [91] treats "work" not only as a physical concept, but gives photographs of pilots, stock exchange brokers and coal miners and then asks: "What is a person's work worth?" The Israeli Curriculum Center published a language unit on science [92] for culturally deprived children and prepares an interdisciplinary unit on science concepts which are used differently outside science.

Where the textbook language is not the students' mother tongue, the addition of terms in the home language can facilitate the acquisition of concepts. The students' text of Integrated Science for Hong Kong [93] adds the Chinese translation of many concepts after the English term. Case [94] suggested techniques to overcome semantic barriers, when science is taught in English to Bantu children.

Project SWNG—Scientific Worlds New Guinea identified specific vocabulary difficulties of high school students in Papua-New Guinea. [95]

But where traditional concepts of reality and causality are different from those accepted by Western science, a translation is not enough. Winter [96] states, that—

> "It has become increasingly clear that belief systems of the culture influence the capacity of the learner to function with the basic assumptions of science: the assumption of order in nature and the potential for control of nature to man's benefit."

Much too little thought has been given to this problem in science education [97,98,99] But even within Western culture, the various disciplines affect the way of thinking of men divergently. A poet has the freedom to use anthropomorphisms when writing about animals; a scientist writing a scientific report should not do it. The same man, writing as scientist or as novelist, will use two different ways of expressing his thoughts. This difference (or the question whether this difference is real or artificial) is seldom made clear to students because of the lack of contact between literature and science curricula—and the respective teachers in school.

Language is an expression of culture. Modern science and technology had an enormous influence on civilisation and culture, but having no intrinsic values they will not be able to replace cultural values and creations. Man's knowledge is growing exponentially, but it did not start with modern science. While the scientist bases his conclusions on carefully planned *experiments,* earlier generations relied on *experience*—a much slower process, but nevertheless one which has contributed much to human knowledge. Many historical accounts, traditions, folklore sagas and proverbs could be used as elements in an integrated science curriculum. The Agriculture as Environmental Science project has done so with Jewish and Arab traditions, [100,101] STEP in Nepal and some emerging African projects appear to go in the same direction.

Books communicate with the reader not only through the written word. Illustrations were found to be important, where pupils are supposed to identify themselves with student activities described in the text. [102] The use of photographs of students at work in science seems to have a special effect on students in developing societies. Therefore integrated science texts in Africa, like Finding Out in Science [103] and booklets of the African Primary Science Program [104] use photographs of local children and their environment most successfully.

3. THE DIMENSIONS OF INTEGRATION

Integrated science programmes have two or more dimensions. The most important are "scope" and "intensity". [105] Other possible dimensions will be discussed later on.

"Scope" refers to the range of disciplines and fields of study, from which content has been used in an integrated science curriculum. The scope of integration gives us an indication of whether the integration was made between similar disciplines or between traditionally removed ones. By "intensity" we mean the degree to which the subject matter has been truly integrated. This idea, too, will be elaborated in a later section.

The Scope

In the second part of this chapter we have looked at integration in science teaching in terms of the subject matter disciplines involved. We can differentiate between widening scopes of integration:

a) Within one of the natural sciences: e.g. arithmetic with algebra and analytical geometry in mathematics; or botany and zoology in biology.

b) Between two close natural sciences: chemistry and physics as physical sciences—apart from life sciences.
c) Between the natural sciences (with or without mathematics).
d) Between basic and applied sciences and technology.
e) Between natural and social studies.
f) Between science and humanities.

Not always is a maximal scope of integration the best. It is, however, most appropriate where children, and specially young children, are left to investigate their own environment freely, according to their own interest. A wide scope will also be used, where a programme or unit is built round a complex problem, taken out of contemporary life. But as the students' investigations reach a higher level of sophistication, the scope will usually narrow.

It should be made very clear that the customary division of human knowledge into disciplines does not imply that in the integration process we try to produce a coherent whole from bits taken on purpose from different disciplines. This might be done in many cases (and some good "synthetic" programmes have been created in this way). A better approach would be to decide first, what educational aims should be reached and then choose, together with the subject matter specialists, the best way to achieve this aim. More probably than not the planners will then come to the same conclusion as the group of scientists, who planned the successful introductory science course for the Open University in Great Britain. As reported by some of them [106] they started out as discipline specialists, who bargained for a fair share for their respective disciplines. But as the deliberations went on, the boundaries fell, and they came up, as a group, with a fully integrated programme, covering a wide scope of the sciences and focusing on science related aspects from both technologies and humanities.*

The Intensity Dimension

We have tried to answer the question "Why integrate" and "Integrate—what?" We now come to the problem of intensity in integration: How much can and should one integrate in science education?"

Already the Varna Congress on the Integration of Science Teaching [107] distinguished clearly between complete integration and the coordination between the disciplines. We suggest a finer distinction—between *coordination, combination and amalgamation* (full integration). Coordination would usually apply to independent programmes taught simultaneously, which were influenced to a varying degree by a common agency, e.g. an educational authority or planning committee. A combined science programme would have chapters or other major units organized round headings taken from the different disciplines, whereas in a truly amalgamated programme an inter-disciplinary topic or issue would form the unifying principle at the chapter level.

In reality programmes are not separated into three clear cut classes of intensity; they are *more or less* coordinated, more or less combined or amalgamated. The trend seems to be a movement from the first toward the latter.

Various factors affect the degree of intensity in the integration of science teaching. Differentiation between the school subjects appears to grow with the student. Technical and comprehensive schools tend to integrate subjects more easily than grammar schools. But above all local traditions and administrative structures have a strong bearing on the integration process. Where strong, national curriculum centres exist the integration process is often facilitated. Where traditionally oriented subject matter inspectorates or university faculties are in a stronger position, they act often as a hindrance. So do inflexible examination systems and sometimes even those who should be first to welcome innovation: the teachers. In such cases coordination and combination of programmes and units can be a first step. As unsatisfactory as this is, such a procedure can lead to a gradual change in attitude towards the introduction of full integration.

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* See example in Part 2 of this book - Ed.

In some countries formerly separated courses are combined, e.g. general science and hygiene-physiology in Nepal. In other cases existing materials of separate science projects are used in more combined and amalgamated projects—as in the newer Nuffield and Schools Council courses. In Israel a similar tendency is felt in Kibbuz schools, which combine the agricultural and biological programmes in Junior High schools.

An integrated scheme can have a very wide scope and still stay on the level of coordination between discipline centred courses. A good example of such an approach is the way the educational authorities in Bavaria treated a problem like sex education. [108] This theme is not restricted to biology. It recurs in many other subject areas, even art (nudity) and religion (ethical aspects of sex). Even in a country with a strong tradition of discipline-based syllabuses, like Germany, new projects widen their scope and intensify their integration effort. The biology group of IPN (Institut für die Pädagogik der Naturwissenschaften), for instance, stressed the need for more coordination between school subjects and produced a motivating unit on "Swimming in Biology and Technology", which integrated elements from sport, biology, physics and technical crafts. [109]

An Integration Matrix

The extent to which a particular programme is integrated can be shown on a matrix, the dimensions of which would be "scope" and "intensity". This matrix can be useful in describing and comparing integrated science programmes.

Many integrated science curricula emphasize their constituent content fields differently. Both the Schools Council Integrated Science Project and Nuffield Combined Science, which are on different levels on the intensity scale, integrate some elements from the applied sciences (although in varying degrees). The former, for instance, refers to social and cultural issues, without treating them systematically (Figure 1).

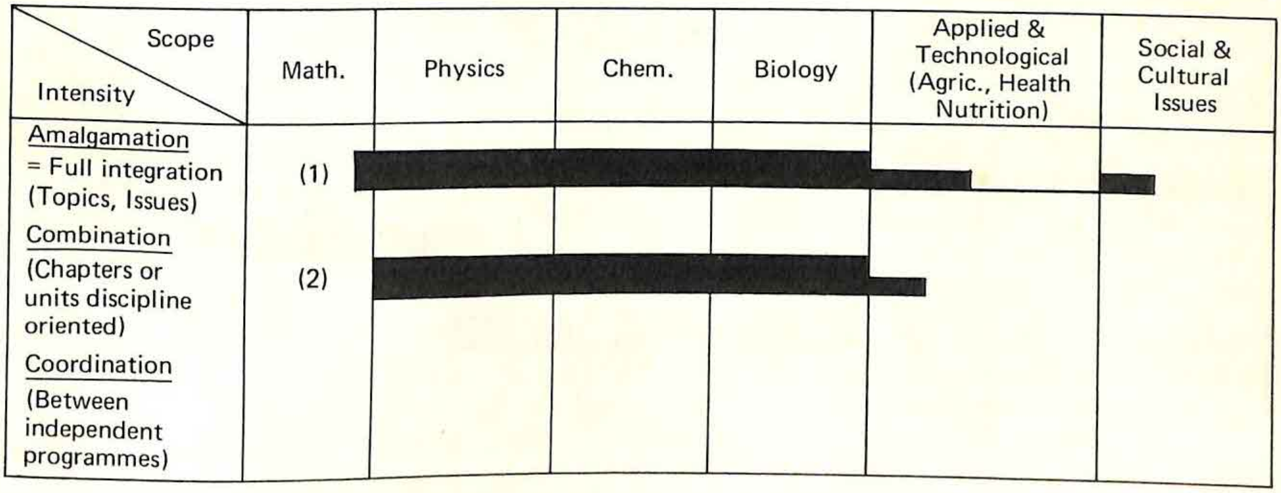
Scope
Intensity
Math.
Physics
Chem.
Biology
Applied & Technological (Agric., Health Nutrition)
Social & Cultural Issues
Amalgamation
= Full integration (Topics, Issues)
(1)
Combination
(Chapters or units discipline oriented)
(2)
Coordination
(Between independent programmes)

Figure 1 Integration Matrix for (1) School Council Integrated Science Project [110]
(2) Nuffield Combined Science. [111]

These aspects can be demonstrated in the Integration Matrix by using a thick line for the main content fields and a thinner line for the units outside this field. The length of the line could give an idea of how much the different disciplines contribute to the programme.

A comparison between the Physical Science Study Committee [112] programme and Harvard Project Physics [113] shows that both integrate with their physics core some chemistry but differ in their approach. (Figure 2). PSSC makes heavy use of mathematics, HPP has a humanistic approach.

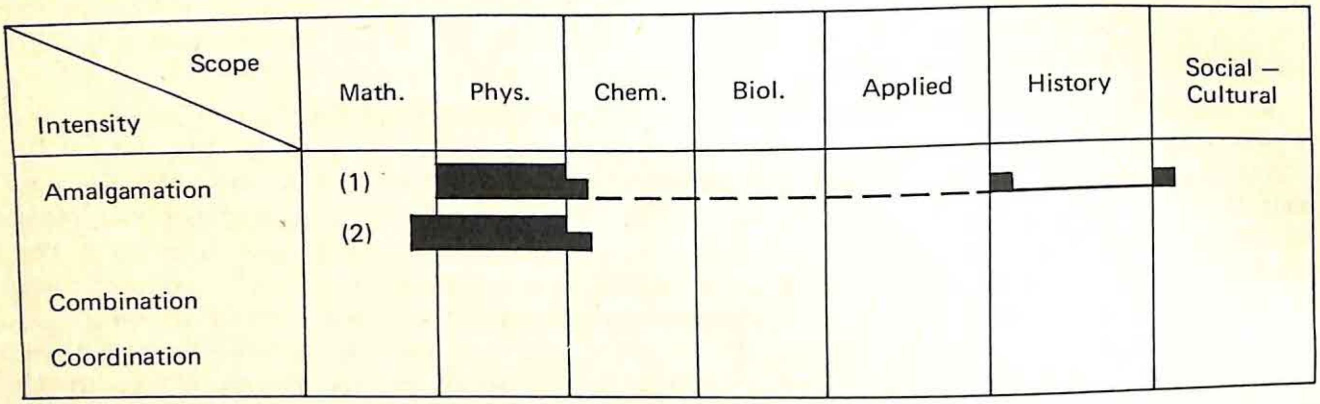

Figure 2 Integration Matrix for (1) Harvard Project Physics
(2) Physical Science Study Committee

In most cases teaching programmes in science integrate adjacent disciplines, but often the integration would be between elements, which do not belong to adjoining content areas. This kind of integration could be shown in the matrix by a broken connecting line, as in the case of Harvard Project Physics.

The matrix can also be used to show the coordination between two (or more) partially integrated curricula. For example the junior high school science course in Israel consists of parallel courses in physical [114] and biological sciences [115] (combined) and an amalgamated Agriculture as Environmental Science course [116], which includes a good deal of biology as basic science and treats some societal and cultural problems. (Figure 3).

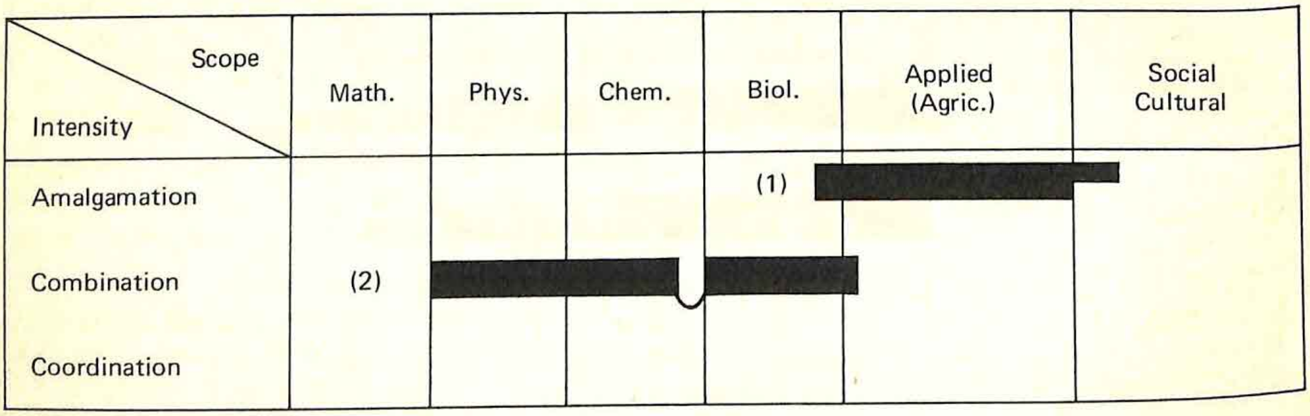

Figure 3 Integration Matrix for (1) Agriculture as Environmental Science
(2) Physical Science and Biology (Junior High, Israel)

These two courses are coordinated at the development level and are often given by the same teacher. A coordinated unit in the language arts, "The World of Science" [117] serves to foster the semantics of science. The relations between these constituent parts are shown in the following Integration Matrix (Figure 4).

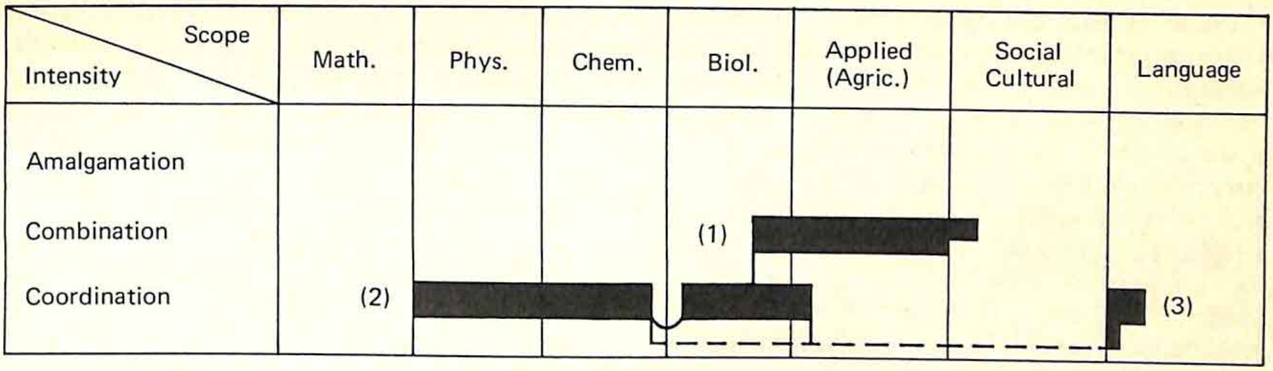

Figure 4 Integration Matrix for Junior High School Science Courses in Israel
(1) (2) as in Figure 3 (3) "The World of Science"

The Integration Matrix can be useful to describe how far a programme is integrated (or claims to be so). The matrix does not show, however, what content should be integrated and how this should be done.

Environmental Involvement—a third dimension

So far we have delineated two dimensions of integration—scope and intensity, which help to define the locus of a science (or general educational) programme in a matrix. The scope of integration defines the subject matter range; intensity is dependent on the organisation of the curriculum.

There are possibly more dimensions to the integration of science teaching. We can ask: How far is a programme *involved* in a range of problems, posed by the *environment* of the learner? Does it lead to the personal profit of the learner as in the form of projects, e.g. as used in Vocational Agriculture in the United States? Does it involve the development of the village and educate towards national self-reliance, e.g. in the Tanzanian Pilot Project? [118] Does it look at problems affecting the biosphere and Man's place within it?

Integrated science teaching is not complete without environmental involvement. Most definitions of integrated science, which were collected by d'Arbon [119] contained the educational aim of "helping the student to gain an understanding of the role and function of science in his everyday life and the world in which he lives." While environmental involvement is a typical constituent of integrated science programmes, it is not restricted to them. Some recent "segregated" courses have gone in the same direction. But wherever they did so, they widened their scope and came nearer to an integrated approach.

In order not to complicate the use of the matrix, we shall not endeavour to depict the environmental involvement dimension graphically. But in describing a science curriculum, its position as to environmental involvement should be pointed out.

The Integrating Principles

Many principles are used to integrate a science curriculum. Some of them are interdisciplinary topics (e.g. "air", "water" in Finding Out in Science [120] and in the Nigerian programme [121]) and draw their integrated content from different science subjects. The posing of an environmental problem like pollution, hunger and population problems, can be another useful integrating principle.

Integration is not necessarily built on content. Other powerful principles of integration are, for example, "common educational objectives" (e.g. analysis of events–in mathematics, science, history, philosophy and arts) or a common method (e.g. inquiry training, problem solving, processes in science). These possible integrating principles come from different dimensions. Two or more of them can be used concurrently. Furthermore they are not necessarily connected to integrated science teaching. "Concepts", "processes", "inquiry" and many more organizing principles are used by curriculum builders also in discipline-centred programmes. Because the integrating principles do not form a continuity of any sort, it is not possible to show them on the integration matrix. A full treatment of integrating principles, their characteristics and philosophical basis, their advantages and disadvantages, and their potential use in curricula is not intended here. It would deserve a volume of its own. The integrating principles are mentioned here only to draw attention to their paramount importance in planning an integrated programme.

Flexibility

Another important facet of science teaching is flexibility. By flexibility we mean here the degree to which chapters, conceptual schemes, themes or topics can be interchanged. Flexibility in this sense is useful as an attribute of integrated science teaching. Two programmes with similar content and identical locus on the integration matrix could differ very much as to their flexibility. One of them might be highly unflexible, such as Science A Process Approach [122], (built on Gagné's [123] learning psychology), the other highly flexible, such as Individually Prescribed Science [124], which leaves the sequencing to the teachers and children. Projects following Piaget's ideas of developmental stages, like Science 5/13 [125] and Science Curriculum Improvement Study (SCIS) [126] would fall somewhere in between.

In practice the flexibility of a programme depends not only on the philosophy of education of its authors. It is strongly influenced by teachers' attitudes and their own intellectual flexibility. There are flexible and inflexible curricula in very narrow fields of study. Therefore "flexibility" is no specific dimension of integrated science teaching. Nevertheless the degree of structuredness should be defined, when a curriculum is described (be it in the form of a monograph or in a catalogue like the International Clearinghouse Report) [127].

Teaching Approaches and Labels

Many labels for integrated curricula are currently in vogue, such as "process", "concept", "topic", "pattern", "applied", "environmental", "relevant" and so on. These labels are used for different things and are not always clearly defined. One programme calls "air", "water"–topics; another uses the same words as "concepts", while "concepts" in other curricula are quite different things like "interaction", "change" and so on.

The adjective "relevant" has very different meanings to whoever uses the term. "Environmental" is used for two quite different things. Sometimes it is defined as "content taken from the near environment of the child", which is quite another thing than "investigating issues, which arise from changes in the physical, biotic, and cultural environment as influenced by Man".

Different teaching approaches are described in chapter 4. Here we would like to point out only two things:

1. A concensus on the use of terms for teaching approaches does not exist. Too often programmes are labelled with fashionable catchwords. Therefore, when referring to a certain teaching approach, the exact meaning of its "trademark" should be carefully defined.
2. These teaching approaches cannot form a fourth dimension of integrated science teaching, because they are not mutually exclusive. "Topics", "themes", "problems" have to do with content and with the way a curriculum is organized. "Concepts" stand for substantive structures, which have both a content as well as a method aspect. "Processes of science" say little about content and more about the syntactical structures of science and the objectives of teaching.

Science is both a process and a body of knowledge. Therefore both must be featured in science teaching. Most current programmes are using many different teaching approaches. Only the *extent* to which a particular approach is emphasized varies from one curriculum to the other. Not only clearer definitions for teaching approaches should replace the labels; we should also be more aware to which extent and in which ways different approaches are used simultaneously to maximise the educational efficiency of the programme. Questions need to be asked, such as *"How much* of a particular approach (e.g. process) is used in a specific curriculum? How much weight is given to concept formation?" It is not easy to measure the relative weighting of each approach in the whole programme. Time alloted to each of them is often unknown, and even where it is prescribed by educational authorities, the educational efficiency cannot be predicted by curriculum workers and is practically never measured.

The number of pages devoted to each approach in students' texts and teachers' guides is also an invalid measure, because texts are only a part (and not always the most important) of a programme. Furthermore, since teaching approaches are not mutually exclusive, two or more can be used in the same unit. Perhaps a better indication would be a statement by the curriculum developers or pilot study teachers of how much they were influenced by different approaches. This statement will then have to be checked by comparative evaluators against the materials of the given project. In any case we should leave the "either–or" approach as expressed by labels and should use a more quantitative and multi-track way of thinking.

As we have seen, flexibility and using different teaching approaches are not unique characteristics of integrated science teachers. But in integrated science teaching we are perhaps more aware of the complexity of the problem and the need for an eclectic approach. We have given up the neat departmentalization and are ready to look at more complex and fluid structures. We have suggested the environmental involvement as an important dimension of integrated science teaching which indicates if programmes are responsive to changing social and cultural conditions. Though some "pure science" programmes too are environmentally involved, this dimension is essential for integrated science teaching. Foreign curricula in physical science can be adopted in another place, and minor changes, mostly due to economic considerations, are enough to make it teachable. Usually more adaptation is needed in the life sciences, though in practice many programmes adapted imported curricula by merely exchanging the original examples of plants and animals with local species. Where social and cultural issues are part of an integrated programme, the adaptation process is more complex. So far no theories or even pragmatic prescriptions have been developed, which could guide science teachers, as individuals or organized as task forces, in their efforts to build an effective programme of integrated science teaching. But with the expansion of the integrated science movement more and more practical experience is gathered and insight is gained into the ways of initiating and teaching science in an integrative mode. It then becomes possible to formulate a more comprehensive rationale, which might help, hopefully, curriculum developers and science teachers to build the courses which are best suited for their students.

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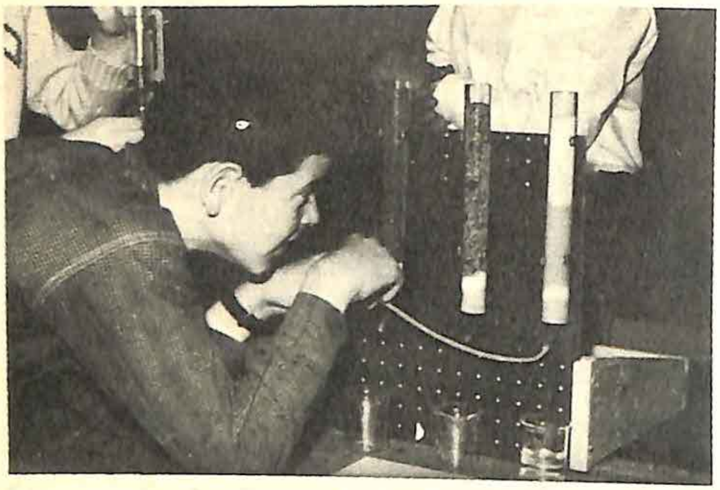

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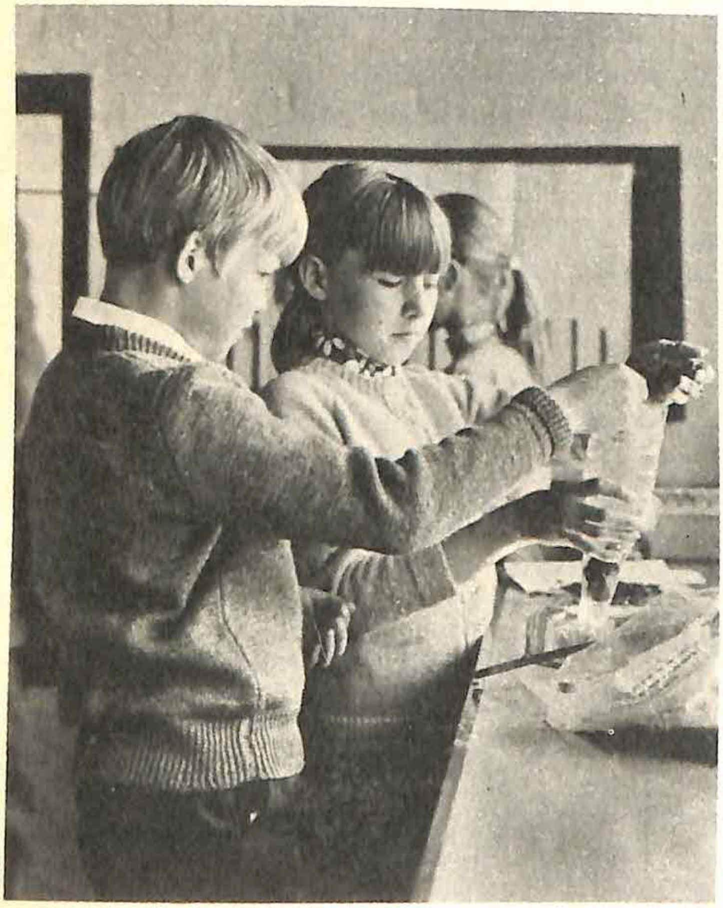

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1. Measuring the water infiltration rate in different soils.
2. Preparing an investigation into the physical conditions governing germination
3. Measuring the effect of different treatments

Chapter 3

CONTENT AND APPROACHES OF INTEGRATED SCIENCE PROGRAMS AT THE PRIMARY AND SECONDARY SCHOOL LEVELS

Herbert D. Thier
Science Curriculum Improvement Study

Summary

The overall intent of the chapter is to emphasize the commonalities found in integrated science programs. These commonalities can be included while providing for a high degree of diversity in the choice of content and approach for any specific program.

First and foremost is the emphasis on the direct experience of the learner as the basis for the science program. No longer is science considered only something to read about in a textbook or simply a series of facts in a syllabus to be learned.

The teacher's role is one of a facilitator of learning experiences, providing equipment and materials and necessary guidance, so as to increase the quantity and quality of learning obtained by the pupil.

The desire to choose experiences that are relevant to the stage of intellectual development of the learner is pervasive throughout the worldwide move towards integrated science for at least the primary and early secondary years of school. It is this concern with the individual and his nature as a learner which forms the philosophical and theoretical foundation for the described emphasis on direct experience and the related change in the role of the teacher.

Following the discussion of commonalities, differences found in integrated science programs are described and discussed. At the primary and early secondary levels these differences are important, but the programs overall tend to emphasize the commonalities described earlier. At the upper secondary level, the chapter emphasizes the need for a rethinking of the purposes of science education.

No longer can science programs at any level be justified by whether or not they get the pupil ready for, or teach him, physics or chemistry, for example. For the individual contemplating advanced training in the sciences, the study of specific sciences like physics should be an available elective.

All pupils, as part of their general education to become contributing members of the society in which they will live, should study science of an integrated nature to help them understand the possibilities and limitations of science and the effects it can and will have on them, their community, country, and world. The overall purpose of such a science program will be to increase the scientific literacy of the population as a whole.

Introduction

Integrated science has been defined as those "approaches in which the concepts and principles of science are presented so as to express the fundamental unity of scientific thought and to avoid premature or undue stress on the distinctions between the various scientific fields." [1] Such a definition encourages a wide diversity, not only in specific topics chosen for inclusion but also in the overall organization and structure of those programs that are considered to be integrated science. This chapter on the content and approaches of integrated science programs at the primary and secondary levels will reflect this diversity, while pointing out and emphasizing certain common characteristics and approaches found in most programs considered to be integrated science. Cultural traditions, social and/or economic limitations, and even the personalities and experience of the program developers may affect the degree to which these commonalities are present in any one program, but on the whole these commonalities, not the differences, express what integrated science is today.

Since most program development in what is here defined as integrated science, has, to date, been concerned with the primary and early-secondary school, one emphasis in this chapter, as in the current UNESCO program, [2] is on the first eight or nine years of schooling. In the first section of this chapter, those characteristics and approaches that are found in most integrated science programs are identified and described. Following this, the major differences in content and approach of primary and early-secondary programs are discussed. The special problems and responsibilities encountered in developing integrated science programs at the upper-secondary level are described in the general context of the limited work that has gone on at this level. Recommendations are made regarding the nature of integrated science programs which should be considered for development at this upper-secondary level. The emphasis at this level, as in all of integrated science, should be on the need to promote the necessary literacy in science which will help the individual to become a contributing and critical member of society in his own country and the world. Furthermore, integrated science, like all other education, should offer the student activities and ideas of immediate interest and use to him, rather than simply preparing him for some future objective.

This chapter can be used as a source of suggested guidelines to aid those involved in selecting content and approaches for integrated science program development projects currently underway or contemplated. The overall intent of the chapter is to emphasize the commonalities found in current programs and considered to be vital to the furtherance of the intent of the whole integrated science movement. These commonalities can be included while providing for a high degree of diversity in the choice of content and approach for any specific program.

COMMONALITIES FOUND IN "INTEGRATED SCIENCE" PROGRAMS

Direct Experience

The basis of all integrated science programs is the emphasis on the learner's direct experience with objects and organisms. No longer is science considered something to read about in a textbook or a series of facts in a syllabus to be learned. This overall point of view is clearly expressed in the *Report of a Regional Workshop on Integrated Science Teaching in the Asian Region.* Throughout, the report emphasizes the need for direct experience, with statements such as: "By a judicious choice of experiences and activities, children learn how to think productively about the natural world and man's interaction with it by calling upon knowledge and skills from the various parts of science as needed." [3] So important is direct experience to the participants who attended this workshop that a whole section of the report is devoted to the need for, and suggested ways of providing, materials to make such experiences feasible in the schools. [4]

The new, proposed *Primary Science Syllabus for Ghana* states that current thinking in science demands that students participate in activities. The report goes on to state: "We think that learning for understanding is better accomplished when children are involved in doing and finding out things for themselves rather than merely listening to another person explaining." [5] This point of view also permeates the proposals of the Junior Secondary Group in its report on the development of a trial integrated science program for use in the first two years of Ghana's secondary schools. [6]

In describing the Malaysian adaptation of the *Scottish Integrated Science Syllabus,* the Deputy Director of Schools for Malaysia, makes the point that "The course is activity centered and the main aim is to encourage pupils to think for themselves in a more objective way." [7] This emphasis on activity and experience, with real materials as the basis for integrated science instruction at both the primary and early-secondary levels, is found consistently in the description of current and planned integrated science projects in various countries throughout the world. Specific examples of such reports can be found in *New Trends in Integrated Science Teaching, Volume 1,* [8] and the *Eighth Report of the International Clearinghouse on Science and Mathematics Curricular Developments.* [9]

The only variations of this point of view are related to the question of who provides the materials. Some programs, because of a desire to leave the specific choice of topics to be studied to the teacher and pupils, provide no materials. Nuffield Junior Science, [10] for example, encourages the teachers and pupils to gather and construct their own materials. This has proved to be quite difficult for many teachers, even in the relatively developed schools of the United Kingdom, and more recent projects provide some materials or specific sources of supply for certain items. Other programs, such as the Elementary Science Study [11] and the Science Curriculum Improvement Study, [12] provide commercially available kits of materials to help accomplish the objectives of given units or a whole basic program. In these cases it is desired that all students have certain basic experiences before going on to more self-oriented individual experiences. Clearly, the teacher's task is made easier in such cases, since he has the necessary materials easily available. Some initial flexibility is sacrificed for the advantage of increased instructional efficiency. In many parts of the world, economic limitations and concerns will be the major factors restricting the provision of extensive amounts of science materials to the schools, especially at the primary level. A more extensive discussion of how to provide materials for the schools will be found in Chapter 6 of this volume.

In spite of these limitations and concerns, the concept, in principle, that integrated science is to be a hands-on, materials-centered program for children is an accepted fact throughout the world, both by curriculum innovators designing programs and by government and local education officials responsible for putting them into effect. This value of direct experience is highlighted in the following statement describing the Science Education Program for Africa (SEPA), an African-directed consortium of countries concerned with educational improvement in science.

> "The main concern of SEPA is to provide meaningful learning experiences for the child. The study of science is regarded as one of the most valuable means of furthering his development by providing opportunities for him to explore his own environment. Children are encouraged to find things out for themselves, to see problems from varying frames of reference and to develop an ability to resolve such problems themselves. Thus they will come to realise their own strengths. They might even learn in the course of their own development to approach problems in other situations with confidence and integrity." [13]

Role of the Teacher

The emphasis worldwide on direct experience for the learner has led to extensive concern about, and recommendations for, changing the role of the science teacher. No longer is the teacher seen as the provider of facts which the children listen to, commit to short-term memory, and then give back on a test. Rather, the teacher's role is one of a facilitator of learning experiences, providing equipment and materials, necessary guidance and motivation, and asking divergent and/or summary and analysis-type questions as pupils work. Differences of opinion exist among various programs as to how much of a role the teacher should take in directing the child's experience along a preselected path, but the emphasis in all programs is on the child's experience. For example, at the primary level, recommendations from development groups in Ghana, [14] Israel, [15] Japan, [16] Korea, [17] and the Philippines, [18] to name a few, all talk specifically about the need to change the teacher's role. This point of view is most clearly stated in the following excerpt from the summary statement of the *African Primary Science Program/Science Education Programme for Africa:* "In this way of teaching, the child becomes the doer, learning from the materials he works with, and the teacher becomes the listener and guide, teaching by posing questions and suggestions." [19] Most important is the fact that this is not the statement of a single, national curriculum group, or the result of just a workshop with outside consultants. Rather, the point of view reflects the policies of the ministries of education of at least seven African countries, each of which financially supports this all-African organization mentioned earlier. As one moves into the secondary school, concern with external standards and examinations, and a tendency to become more concerned with "content learning," affects the specific role described for the teacher but the intended role of the teacher as a facilitator of learning experiences does not change.

At the early-secondary level, one finds this same role described for the teacher. However, there is increasing concern about the science background of the teacher, since all of the junior secondary courses tend to have specific, content-oriented goals. Since the desire of integrated science programs is to have the pupil achieve this content knowledge in an investigative way, the responsibility placed on the teacher is even greater. The ways in which the format of the program changes the possible roles available to the teacher are emphasized in a preliminary publication of the new, early-secondary science project in Sierra Leone. [20] The introduction to the first unit called Vision emphasizes the fact that when children are involved in small group work, the teacher is able to use the resulting activity and interest level in all groups to enable him to spend his time discussing the work with one group at a time. This helps contribute to the meaningful individualization of the program according to this report. In an introduction to a modification of the *Integrated Science Syllabus* for the *Junior Secondary Schools of Nigeria,* the teacher's job is described as being more difficult. It goes on to state: 'He (the teacher) must allow the student to do much more practical work than he has done in the past: practical work that will help the student to answer a question rather than to verify a statement. This will, of course, demand much more advanced preparation on the teacher's part and will require efficient laboratory organization." [21] What is implied here and in other programs, such as the Intermediate Science Curriculum Study, [22] and the various Nuffield secondary projects, [23] is a teacher who has command of both the subject science and the processes involved, both in knowing and teaching it.

The new role of the teacher is described clearly in the *Science for General Education* course developed for the first two years of the secondary schools in Scotland. It is important to note that the philosophy and the content of this course is being used, with local adaptation, in a number of developing countries throughout the world. In the section titled "Teaching Methods," the following statement is made which expresses the dominant point of view worldwide, both at the elementary and early-secondary levels:

> "We have already made clear in the statement of aims that we see science contributing much more than factual knowledge to the education of children. Thinking, communicating instrumentation, experimentation, and, most important of all, creativity are all dependent for proper development upon selecting the right methods for presenting science to these young people. It is surely the concern of all teachers of the sciences to ensure that the subjects are taught in such a way that creativity in dealing with abstract ideas, with experimental situations or with developing new apparatus or instrumentation, is encouraged and fostered." [24]

Nature of the Learner and His Need for Science

The emphasis on direct experience with real materials and the desired change in the role of the teacher are goals of "integrated science" programs worldwide. These goals have been adopted as a result of a significant rethinking concerning the nature of the learner and his need for science. In addressing both these points in relation to the question of what kind of science should be provided, the LMN project, a major primary school curriculum reform effort in Sweden, [25] states, "Another alternative (the one they selected) is to choose general working concepts. Using these concepts, the pupil will have the possibility to interpret scientific problems emerging in his life, as far as his psychological stage (development) allows. The LMN project has found that the SCIS, [26] project materials can help solve the problem of what general working concepts to choose." The report goes on to state:

> "To make the teaching efficient it is necessary to range the concepts in a certain order or sequence according to logical foundations, but it is also important to pay attention to the psychological development of the child. Thus the structure will be both logical and psychological. As it is necessary to erase the dividing lines between the different subjects, especially between science and sociology, it is essential that the concepts are as cross scientific as possible. We have found that the concepts can be chosen so that language development might also be facilitated."

At the primary level the emphasis is on science as part of the general education of the child. This relationship of science to general education is described more fully in Chapter 9 of this volume. Especially in the developing countries of the world, science is considered a most important part of the educational experience of the child. In addition to providing him with information about, and an understanding of, his total environment, science is also suggested as a way of building problem-solving and decision-making skills in the young, which are considered necessary for the continued growth and development of the country. This point of view is clearly expressed in the following statement from the report of the regional workshop on Integrated Science Teaching in the Asian Region: "It is now widely realized that if the teaching of science is to meet the needs of societies which are rapidly becoming more technological, then science in schools can no longer be thought of as 'pure' discipline divorced from life. Science and technology are influencing people's lives and changing them to such an extent that effective science education must concern itself with this influence." After giving as examples a number of environmentally oriented problems, such as population, nutrition, and health, which must be an integral part of the school science curriculum, the report goes on to describe the need for a multi-disciplinary approach to science including aspects of what has traditionally been considered social science. In summary, the point is made that "science teaching must be *problem-oriented* concerning itself with problems of direct relevance to the child and to the community in which he lives." [27]

The importance of relating science education to the specific needs of the developing society is clearly expressed in the report of the Sub-Regional Conference on Curriculum Development held at the University of the South Pacific. After emphasizing that, whenever possible, science content should be selected directly from the pupils' environment, the report goes on to state:

> "In the wider sense the content of the course should highlight the significance for society of scientific knowledge. In the South Pacific, one important way of highlighting this is to use materials which have immediately practical applications for the pupil, for his community and for his country. The possibility of linking the content to agriculture and technology and to the social implications of science are particularly important criteria whenever a choice of content for a unit is under consideration. By a careful selection of units of work, natural links with agriculture, technology, mathematics and society should become evident." [28]

This emphasis on providing meaningful science education for all as a way of developing the individual's way of thinking, while also encouraging an increase in the number of highly trained individuals to meet the technological and societal needs of the developing country, is emphasized in the reports of integrated science projects at the early-secondary level in various developing countries. Reports from Nigeria, [29] Malaysia, [30] and other countries emphasize both of these points in discussing the secondary school pupil. As might be expected in the so-called "developed" countries of the world, the emphasis in all integrated science programs is on the importance of science for the development of the individual as a member of the society with little or no emphasis on science as professional training. The importance of emphasizing the relationship between the science chosen and the intellectual development of the child is expressed in the statement of the broad aim of the Australian Science Education Project (ASEP) for grades 7-10.

> "The broad aim of the project is to design science experiences which contribute to the development of children. Science is justified in the junior secondary curriculum because science experiences contribute in unique ways to the personal and social development of children. The project will seek those experiences which best contribute to this growth and are relevant to the stage of development of the students. The project is less concerned with the training of future scientists and technicians." [31]

This concern with choosing experiences which are relevant to the stage of development of the learner is pervasive throughout the worldwide move towards integrated science. In fact, it is this concern with the individual and his nature as a learner which forms the philosophical and theoretical foundation for the emphasis on direct experience and the change in the role of the teacher which, as described earlier, are fundamental to most of the currently used integrated science programs.

Much of the research done on the individual learner and his development has been carried out by Piaget, [32] and his associates working in Geneva and elsewhere. Whether or not one accepts Piaget's specific description of developmental stages and how the child proceeds from one to another, the implications for science education are extremely important. This relationship between Piaget's work and science education is discussed more fully elsewhere, for example, in "With Objectives in Mind," [33] the rationale for the Nuffield Science 5-13 project, and in *Teaching Elementary Science, A Laboratory Approach,* [34] a text for prospective and inservice teachers. In fact, it is difficult to find a rationale for a science project or a text in the field that does not discuss and use the ideas embodied in Piaget's work.

Applied to the science program, Piaget's findings indicate that activities and concepts chosen for the early years of primary education should be concerned with real objects and their immediate observation, with description and discussion of what happens between objects (interaction) taking place only after the experience and in direct relationship to the action. Children of this age are not particularly adept at drawing logical conclusions or relating one experience to another. Somewhat older children (middle years of primary school) are able to carry out some mental manipulations in regard to their observations. For example, ideas of conservation and reversibility are becoming part of their way of thinking. The science program, still evolving from direct experience, can now emphasize the handling of variables and solving of problems in a more quantitative and orderly way. As the child becomes older and moves into the upper years of the primary grades and the beginning of secondary education, he becomes more capable of dealing with abstractions, making predictions about events he has not observed, and hypothesizing the outcome of a new occurrence based on his previous experience with related phenomena. This capability for abstract thought develops slowly and the science program, to be meaningful, must still emphasize the concrete and the real through the use of materials to encourage this kind of thinking. In all of the reports of projects and conferences on integrated science cited earlier in this chapter, one finds this concern with the development of the learner emphasized over and over and used as the basis for the insistence on direct and extensive experience by the learner with the objects and organisms which make up his overall physical and biological environment. Essentially, what is required is the continued design of meaningful science activities and programs that take into consideration the development of the learner. They will then prove to be interesting and involving for the pupil as he develops and grows towards becoming a scientifically literate, participating citizen in his society.

This review of commonalities found in integrated science programs started with the emphasis on direct experience and, after discussing the related need for change in the role of the teacher, returns to the emphasis on experience when considering the nature of the learner and his need for science. Keeping these general commonalities in mind, we will look at the differences found in the general content and approaches of integrated science programs for the primary and early-secondary levels in the next section.

DIFFERENCES IN THE CONTENT AND APPROACH OF INTEGRATED SCIENCE PROGRAMS AT THE PRIMARY AND EARLY-SECONDARY LEVELS

Each of the integrated science programs at the primary and early-secondary levels are concerned with, and stress the points discussed in, the previous section. When one analyzes the specific content and approaches to instructional planning of the individual programs, however, significant differences become apparent. An introduction to most of the major integrated science programs, as well as sources from which further information can be obtained, are given in the *Eighth Report of the International Clearinghouse on Science and Mathematics Curricular Developments* previously cited. It is recommended that individuals concerned with differences between specific programs consult this excellent guide and contact the programs they are interested in for further information. A valuable summary and description of programs currently under development in the various countries of Africa are contained in the workshop report, *Planning for Integrated Science Education in Africa.* [35]

In the next two subsections of this chapter, major differences in the primary and then the early-secondary programs will be discussed. As one looks at these areas of difference, it is important to keep in mind that the commonalities discussed earlier are what characterize the basic teacher-learner interaction at the heart of these instructional programs. The differences are primarily in the areas of overall organization of the program, specific content and topics selected for inclusion, and the degree to which the teacher is expected to use specific units or parts of the program.

Primary Programs

One of the major differences in the various primary programs is the degree to which they specify what topics or units are to be taught and in what order. The variation goes all the way from the Nuffield Junior Science Program, [36] which simply suggests some exemplars and expects the teacher to devise and carry out his own units, to Science–A Process Approach, [37] which specifies all the materials and the order in which they are to be used. Most programs are somewhere between these two extremes, with some, such as Science 5-13, [38] the Elementary Science Study, [39] and the African Primary Science Program, [40] developing various specific units and leaving the choice of which units to use and how to sequence them to the individual teachers and schools. Other programs, such as the Science Curriculum Improvement Study, [41] and *MATAL–the Israel Elementary Science Program,* [42] offer units in a recommended sequence that schools are encouraged or expected to adopt. Since many of the groups developing units only suggest grade levels at which they should be used and the groups recommending a specific sequence frequently provide many options between and within the various units, these differences become somewhat blunted. Furthermore, since most teachers and schools at the primary level have significant freedom of choice as to what materials they will use, these differences may not be very important. In future years we may see schools, school systems, and/or ministries of education selecting from various sources of materials to put together what they consider to be the "ideal" program for them. Such decisions require direction and leadership at the level of decision-making and implementation, and are more difficult to put into effect than the adoption or adaptation of an already available program.

Whether the decision is to adopt or adapt a given program, to put together materials from various programs, or to develop a total program locally, the basic commonalities regarding pupil experience, role of the teacher, and the nature of the learner mentioned earlier should be included. In addition, the program should provide the learner with diverse opportunities for experience in using and coming to understand the various processes or approaches of science such as observation, design of experiments, handling of variables, and so on. It is equally important to consider the goals or objectives one has for the learners regarding the conceptual structure or major "content-oriented" ideas of science. If one goal of science instruction is to make pupils more aware of, and concerned about their social and biological environment, then one approach would be to plan a series of experiences and/or units which accomplish this goal. For example, the decision to design a sequence of units in the life sciences leading to some understanding of the major conceptual idea of the ecosystem enabled the Science Curriculum Improvement Study to develop a life science program which has been cited by the Environmental Study Board of the National Academy of Science (USA), [43] as "most promising for environmental education, because it centers attention on biological and ecological questions." This same goal of increasing the pupils' awareness of, and concern about, his environment could be accomplished by selecting individual units from one or more of the programs whose output is simply units without any sequence, or one could internalize the basic philosophy found in all of these programs and develop their own materials.

By reviewing these differences in content selected and degree of structure recommended in the various primary programs, one can get a feel for the important diversities which exist in this area where there are so many elements of rather complete agreement. Which approach or approaches should be selected by a given development team or user in a specific place at a given time should be based on the competencies of the team, the prior experience of the users, economic considerations, and other specific local needs and requirements. There are no right or wrong decisions on approach, but rather the need, within the agreed-upon basic philosophy, to "fit" or "match" a program or its development to the needs and interests of the learners and the resources and development capabilities of the educational organization responsible for their learning.

Another significant variable found in the different primary school programs is the amount and kind of materials provided for the teacher and pupils. All programs have books or booklets for teachers which describe the philosophy, rationale, and approach of the program and at least give examples of how these were applied in past experience with children. At the other extreme, one finds highly developed teachers' guides that spell out specific objectives for each science session and describe exactly how one is to accomplish those objectives with the children. Most of the programs described earlier as consisting of units placed in a preselected sequence, offer considerable guidance to the teacher while trying, by means of optional activities, projects or further investigations, to retain a high degree of freedom in the teaching-learning interaction. Printed materials for pupils with an emphasis on record keeping and analysis are provided or suggested by most programs on an as-needed basis. This leads to great variation between and within programs as to the amount of such materials provided or suggested in different units or even at different age levels. There is a definite tendency to provide or suggest more student record keeping and analysis as the pupils become older.

All of the integrated science programs at the primary level are based on the extensive use of real materials and equipment so pupils can have their own direct experiences in science. Which materials are provided, if any, is another significant difference found in the various programs. The decision is partly philosophical, since a program that expects the teacher to develop his own units can do no more than suggest a broad range of science and construction materials which might be available. Programs suggesting specific units or sequences of units can provide lists of necessary equipment and materials, including specifications or kits containing the actual items. The availability of kits of materials necessary to teach the unit or sequence makes the task much easier for the teacher. Whether to provide such kits is frequently a political and economic decision, rather than an educational one. At the very least, if teachers are expected to use specific units, the specialized (not locally available) equipment and materials must be provided or specific instructions for constructing such pieces must be given. Having the necessary equipment and materials available is essential to carrying out science teaching of the kind we have been discussing. As obtaining materials becomes more and more difficult for the individual teacher, the tendency will be to return to a lecture type of science program, if to any science at all.

Early-Secondary Program

Almost all programs at the early-secondary level suggest a specific sequence of topics and ideas, with the major differences related to the topics selected and how they are organized. The trend is to move away from a concern with isolated facts and to emphasize broad conceptual ideas such as energy or the ecosystem. Frequently the specific decisions are determined by the need, real or implied, to prepare pupils for external or standardized examinations or for upper-secondary courses which lead to such examinations. Since what is considered upper-primary or early-secondary education varies from country to country, and even within the larger countries, much of the prior discussion of primary programs applies at the early-secondary level.

Other differences which exist in current, early-secondary programs for integrated science are the degree to which the program is divided into physical, life, and earth sciences and who is expected to teach the program. These are two sides of the same question, since most decisions to keep the physical and life sciences, for example, somewhat separated are based on the premise that teachers are prepared in either the physical or life science and not both. Some plans recommend or suggest the use of teaching teams and, of course, this makes more feasible the selection of overall conceptual ideas, such as energy or change, and the use of examples from both the life and physical sciences. What is needed are teachers whose own training emphasized an integrated approach to science.

One additional important difference found at the early-secondary level is the number of different topical areas of science included in a program. The emphasis in new programs at the early-secondary level is generally one of depth, rather than breadth. There seems to be general agreement that the superficial survey of many, many topics, which characterized the "traditional" general science courses so popular at this level a number of years ago, is no longer wanted. On the other hand, there is considerable difference of opinion as to how intensive or extensive a course at this level should be. In regard to this question and others, it appears that the further design, development, and implementation of integrated science programs at the early-secondary level is being seriously held back by the currently prevalent, single-subject orientation of the upper-secondary school. This influence is especially felt at the upper end of the early-secondary sequence.

Since, in many countries, the early-secondary school is the last time that a significant portion of the school population will study science, an emphasis on integrated science, stressing the requirements and responsibilities of the learner as a citizen, is necessary. Examples of two new and promising trends in this direction are: (1) the Human Sciences Curriculum Project, [44] (ages twelve to fourteen), which is beginning the development of a series of units that will emphasize concepts which overlap both the life and social sciences; and (2) Instructional Strategies in Outdoor Biology (OBIS), [45] which is beginning the development of models for teaching outdoor biology to learners eleven to fifteen years old. A major feature of the latter project is its concern with education in the whole community, rather than just the classroom or school. Because man now lives in a managed environment, strategies are being developed for the study of such environments. The early thinking of both of these projects and the Environmental Studies Program, [46] reflect the concept of expanded and life-long education as recommended in "Learning to Be," [47] published as the report of the UNESCO International Commission on the Development of Education.

INTEGRATED SCIENCE AT THE UPPER-SECONDARY LEVEL

Any attempt to compare the development of the integrated science movement at the upper-secondary school to the same movement at the primary school is as much a contrast in educational philosophies, objectives, and approaches as it is a discussion of science curriculum development. Emphasis on, and acceptance of, the importance of science education at the primary level is rather recent. Instruction is primarily related to the developmental nature of the child and his need for science as an integral part of his education to become a contributing member of the society in which he lives. The intent is to provide science for all children. Such an emphasis has led to the development of, and the continuing work on, the kinds of programs described earlier in this chapter. Conversely, at the upper-secondary level science education has a long and varied history and has contributed to the major emphasis of the secondary school which has been preparation for university entrance. In most countries, "developing" or otherwise, upper-secondary education is a program for the "intellectually elite" (as defined by expectation for admittance to higher education). Even in the United States, which essentially provides education for all through to high school graduation (eighteen years old), various plans and schemes have evolved which isolate the college or university preparatory students. This emphasis on preparation for university entrance has led to upper-secondary science courses worldwide that can be characterized as subject-centered (chemistry, physics, or biology) and highly controlled by nonlocal syllabi and external examinations. This situation is reflected in the whole way of thinking one encounters when investigating the so-called movements towards integrated science at this level. For example, the combination of botany and zoology into a single biology course is considered an early example of integration. A true statement, but a most limited concept of integration when compared to the kind of integration stressed in this chapter and volume.

The development of courses such as BSCS Biology, PSSC Physics, Harvard Project Physics, CHEM Study, CBA chemistry, and the Nuffield "O" and "A" level courses in the various individual sciences, have made a significant contribution towards the possibility of meaningful integrated science courses at the upper-secondary level. These courses share an increased emphasis on the laboratory approach, a concern for the learner, and a carefully thought-out consideration of the modern nature and scope of the discipline and its relation to science as a whole. Thus they provide a most useful source of activities, ideas, and approaches for those planning the development of truly integrated science courses at the upper-secondary level. The more usual approach of combining topics from one or more of the traditional sciences to form a new two-or three-year course has been the prevalent "experimental approach" for over twenty-five years in many countries of the world. The Federation for Unified Science Education (FUSE), [48] publishes an excellent bibliography and other materials documenting this and other somewhat more innovative work in integrated science. The director of the Portland Project, which started as one of the leading such combinatorial projects in the United States, summed up this philosophy and approach in the following statement:

> "A variety of integrated courses are appearing today. This suggests there is no one 'right' road to achieving a good end result. The Portland Project, of which I am co-director, seeks to develop an integrated, three-year sequence in biology, chemistry, and physics for secondary schools. The main focus of this sequence is to present science as a unified discipline utilizing "logical content development." This content is conveyed in such a way that students have the most up-to-date view of the structure of each of the disciplines and the total structure in combination." [49]

The emphasis is on a new way of knowing the subject disciplines, rather than on the general educational needs of the individual. Early output of this project seemed to be a synthesis of various topics and chapters taken from the various "new" American secondary-school projects such as PSSC, CHEM Study, CBA, and the BSCS biology. In this way it seemed similar to the first output of the Science Foundation for Physics Integrated and Coordinated Science Textbook Project for the New South Wales Six Year Science Courses. [50] Recent and current work of the Portland Project indicates much greater concern with the overall question of integrating themes and has led to the design and development of an increasing amount of original material specifically for the project. [51]

This approach of emphasizing the nature of science, rather than simply combining the traditional, separate science subjects, is the expressed purpose of a relatively new English project called the Schools Council Integrated Science Project. [52] The overall purpose of the project is to provide a broad integrated course in science for academically more capable thirteen- to sixteen-year-old students, with an emphasis on the social implications of science. It is expected that completion of the course will give the student double "O" level certification in science and provide him with the background necessary to undertake advanced or "A" level science courses which are offered for the academically able at the end of the English secondary school. The companion Nuffield Secondary Science course provides an integrated approach to science for those students (the majority) who will not be going on to "A" level science. The following course description emphasizes the integrated nature and the desire to relate the course to the student's need for science as a citizen, not a specialist:

> "Much of the Project is concerned with investigations which the pupils carry out and which are related to problems having significance for them. This work is designed to give the pupils a wide variety of experience, responsibility for their own work and a feeling of achievement. Through discussions which support each investigation, pupils are encouraged to develop and express their ideas and to develop generalizations so that certain important scientific concepts can be established. These are reintroduced in different contexts, thus consolidating the pupils' understanding." [53]

These rather recent developments and changes in emphasis in England and the United States are extremely important to the future of integrated science at the upper-secondary level. Their long-term impact will be determined to a large degree by how effectively they can influence the university entrance procedures and external examination content in their respective countries. Decisions made in England and the United States will have a very significant effect on secondary education in many of the "developing" countries of the world which, for a variety of reasons (tradition, desire to qualify students for advanced education, etc.), base their educational systems on what they understand to be the current situation in these two countries. For example, Winter, in his study of science education in Asia, states:

> "Perhaps the greatest problems for curriculum reform, however, are the examinations . . . It is particularly ironic when science teaching fails to stimulate curiosity, to demand observations, measurements, hypotheses, deductions, and evaluations. Science is knowledge won by these processes. Scientists achieve excellence recognized by their peers through their skill in applying them. Yet, these skills, these intellectual capabilities do not develop in the pupil without nurture or when they are displaced by rote. In many of the Asian nations, therefore, examination reform is perhaps the largest single step toward more effective science instruction." [54]

This same point of view was emphasized in "Changing The Curriculum," [55] a UNESCO conference at which the participants identified change in the system of external examinations as the number-one priority for bringing about needed curriculum development at the secondary level in *all subjects.* In talking about secondary school science in particular, the conference participants stated, "The major obstacle to the development of science education courses which are relevant to the local situation is the external examinations system." [56]

As described earlier, when one analyzes most of the previously developed upper-secondary programs described as integrated or combined science, it becomes clear that the rationale for their development was to accomplish the objectives of biology, chemistry, and physics or all three through this new course. The tradition of separate sciences at this level is a strong one, and it is reinforced by the above-mentioned systems of external examinations and school graduation requirements found in most countries. That is, to receive a given kind of school certificate or be eligible for university or college entrance, one must pass an examination or have successfully completed a course or courses in one or more of the separate sciences. As long as this tradition and/or requirement is prevalent, the development of truly integrated science programs at the upper-secondary level will be seriously hampered. Since the university entrance and external examination requirements in the United States and, especially, England so directly affect educational decisions in many developing countries of the world, modification or elimination of these requirements in these two countries will have a significant effect on the future development of integrated, upper-secondary science education in many countries of the world.

What is needed generally is a rethinking of the purpose of science programs for individuals at the upper-secondary level. The number of students who will go on to professional or technical-level careers in science, technology, or related fields is limited, and even in these cases there is no evidence that such preparation need start at the secondary-school level. In fact, most technical and professional level programs at colleges, universities, and technical schools start from the premise that the student has no background in the field. In addition, most research and development now underway in the sciences and technology is cross-disciplinary in nature and requires a broader understanding of the interrelationships of various scientific fields. The study of specific sciences like physics should be an available option for the student contemplating advanced training in the sciences, just as he elects other courses because of other special interests. Looked at in this way, these discipline-centered courses will evolve into more meaningful courses for those learners specifically interested in physics or chemistry, for example, since the teachers and curriculum developers in these fields will no longer be burdened with the dichotomous task of teaching the discipline while trying to meet the need for science education of all students.

As part of their general education to become contributing members of the society in which they will live, students should study science of an integrated nature to help them understand the possibilities and limitations of science and the effects it can and will have on them, their community, country, and world. Such a science program will, of necessity, give careful consideration to environmental questions and the possibilities and problems involved in further technological development. The overall purpose of such a science program would be the increase in the scientific literacy of the population as a whole. Needless to say, such programs of a meaningful nature will not be easy to produce and will require an extensive commitment of resources for a significant number of years. The availability of such programs will be especially important for the preservice science education of future teachers of integrated science at the primary and early-secondary level.

No longer can science programs at any level be justified by whether or not they prepare the student for, or teach him physics or chemistry, for example. Rather, science teaching beginning at the early primary level and lasting for as long as the individual remains in school, should choose its content and approaches based on the learner's need to become a scientifically literate and productive member of his society. Such an approach will lead not only to a greater emphasis on integrated science, but also to increasing integration between what has traditionally been the sciences and other disciplines in the school curriculum.

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2. How big is a coconut?
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Chapter 4

TEACHING METHODS IN INTEGRATED SCIENCE AT THE PRIMARY AND SECONDARY LEVELS

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Summary

The paper outlines a spectrum of teaching methods ranging from textbook teaching, through chalk and talk, demonstration and class activity methods to individualised instruction. The spectrum reflects increasing student involvement in the teaching-learning situation. Within class activity methods a similar trend is found from simple practical work, through structured discovery (typical of first generation curriculum development projects) to directed and open enquiry methods typical of modern integrated science courses. In these methods practical activities are more varied and less sequential; the teacher works frequently with small groups and may use worksheets to direct the activity and to stimulate thought and discussion. Circus techniques and the use of kits are discussed as well as the resources required for this sort of teaching. Finally some of the problems of introducing integrated science are raised, and it is suggested that the newer methods may prove to be very helpful to young teachers.

Books and articles on methods of teaching science are usually disappointing and frequently quite useless. This is almost inevitable. The art of teaching lies in creating good learning situations and responding creatively to situations as they develop. I doubt whether anyone would disagree with this last sentence, but the fact that I have written it does not help anyone to achieve this end. The teacher who reads a book on methods presumably wants to know how to create good learning situations in a particular context with a particular class and to go on doing so for a long time, but at best he gets exciting glimpses of what he might achieve and these fade quickly when he is next faced with a class. Since I could not hope to do better than this in the course of a few thousand words I should start by defining more limited objectives. I shall attempt to outline various teaching methods and to discuss whether there is any way in which the reader can learn more about them, short of spending six months with Mr X in school Y in country Z. I shall consider fairly well established methods as well as pioneering methods, and refer to teaching methods in the separate sciences if these are likely to be applied in Integrated Science.

It appears to me that teaching method has three facets: Personality, Strategy and Philosophy. This chapter will be mainly concerned with Strategy, in which I include the organisation of time and resources, the planning of student activity and the deployment of skills, but it is clearly impossible to isolate Strategy from Philosophy and Personality. The teacher's own philosophy of education, the philosophy of the curriculum (whether it be planned within the school itself, by a curriculum development team or an independent author) and the underlying philosophy of the whole school system will all influence teaching method. Other chapters in this volume are concerned with the philosophies of various Integrated Science curricula and these will influence teaching methods directly since the philosophies are philosophies of learning rather than of science. Changes in the underlying philosophy of the whole school system may also bring about changes in teaching methods. In the United Kingdom at present many of the newer trends in science teaching arise from the need to teach a much wider ability range in comprehensive schools, and often in the same class, rather than from the nature of integrated science as such.

Some writers have seen the move to integrated subjects as a change from subject-centred to pupil-centred education and even as a move towards the democratisation of education [1,2,3]. Science teachers may be carried along by these trends, but they themselves may also provide some of the impetus. It should be borne in mind that methods developed to meet the needs of one pressing situation will not necessarily be appropriate in another, though they may prove to be so.

The teacher's style, the way in which he or she talks to and establishes a relationship with a class is obviously an important factor in teaching method, but it may be a reflection of the way in which a teacher is expected to behave rather than of basic personality. The dogmatic, authoritarian, distant teacher may be a helpful, easy-going, sociable neighbour. In this way a teacher's philosophy, or society's view of what a teacher ought to be, may cramp his teaching style. It is also true of course that a teacher's personality may limit his philosophy and the teaching strategies that he can adopt. Some interesting empirical (observational) studies of teachers' styles have been published, mainly based upon the Interaction Analysis of Amidon and Flanders [4] and the Verbal Interaction Category System of Amidon and Hunter [5]. In these studies an observer notes down at regular intervals in a lesson whether the teaching is questioning, presenting information, developing student's ideas, accepting ideas, praising or criticising etc. and whether pupils are responding to questions or initiating discussion, or whether silence or confusion reigns. These systems are not specifically related to science teaching, neither do they claim to identify ideal teaching styles (every teacher's ideal style is presumably different) but they do indicate that teachers who are able to lead pupils through learning situations by indirect influence, that is by questioning, prompting or leading rather than by direct teaching, informing, directing, explaining, produce rather different results. Their pupils are less dependent and generally learn more effectively. Johnson [6] has carried out a comparative study in Sierra Leone, using a modified form of the Amidon and Flanders schedule which includes non-verbal as well as verbal categories, comparing teachers using African Primary Science Project [7] teaching materials with a control group using conventional materials. He found that APSP teachers were less directive than the control group and that their pupils worked more independently. Yoloye [8] comments on the difficulty of establishing fully comparable control groups but recognises that the technique is a promising instrument for evaluating the impact of teaching styles. Such studies also suggest that the adoption of the new curriculum materials (presumably accompanied by some briefing or training) may be successful in helping teachers to change their teaching styles and methods. Kerr and Eggleston [9] of the University of Leicester (U.K.) are currently conducting an evaluation of science teaching methods in secondary schools using a similar technique and are hoping to evaluate the effectiveness of each style by measuring pupils' scores on attainment and attitude tests. Time lapse photography is being used in the Australian Science Education Project [10] to provide a photographic record for a similar analysis.

A further aspect of Interaction Analysis is the study of Language in the Secondary Classroom by Barnes [11] based on lessons observed in the first year of secondary education, several of them being science lessons. The value of this study is twofold, first in drawing our attention as science teachers to the differences between the language of the classroom and the students' everyday speech and how difficult it is for the student to comprehend patterns of speech that teachers take for granted. (This applies when the language of instruction and the student's mother tongue are the same; where these differ the difficulties are compounded). Secondly Barnes analyses the questions asked by teachers and distinguishes between open questions, to which the teacher would accept many answers as a basis for continuing the discussion, closed questions, which have only one acceptable answer and questions which, though superficially open are in fact closed by the teacher's determination to secure a certain answer. The types of question which a teacher is skilled in asking affect teaching method considerably. See also Bellack's work "Language of the Classroom" [12].

The studies described so far do not in themselves represent trends in teaching methods as much as trends in the study of teaching methods but they do provide new and important insights into teaching.

THE LITERATURE OF METHODOLOGY

There are a number of books which deal with the methodology of science teaching, excluding those that deal with the teaching of the specialist disciplines, and those whose main concern is the philosophy of science teaching. British books e.g. The Teaching of Science in Secondary Schools [13], Teaching Science at the Secondary Stage [14] and the Unesco Handbooks e.g. The Teaching of General Science in Tropical Secondary Schools [15], The Teaching of Science in Tropical Primary Schools [16] are inclined to devote a lot of attention to laboratory management, apparatus, buildings, course content and examinations, with more limited attention to teaching methods; demonstration techniques receive the best treatment. American authors e.g. Brandwein, Watson and Blackwood "Teaching High School Science: A Book of Methods" [17] and Kuslan and Stone "Teaching Children Science: an Inquiry Approach" [18] are inclined to be more philosophical and voluminous. All these books have valuable features, but they suffer from the disadvantage, already referred to, that comment on teaching method is generalised to a point where it almost ceases to be helpful. One of the most straightforward and helpful accounts of teaching method, mainly at the secondary level is Massey's "Patterns for the Teaching of Science" [19]. At the elementary level Thier's "Teaching Elementary School Science: A Laboratory Approach" [20] and Anastasiou's "Teachers, Children and Things: Materials-Centred Science" [21] are both helpful guides to modern methods for science teaching at this level.

There are currently available some excellent collections of readings on science education at both the primary and secondary levels [22,23,24,25,26] which involve elements of methodology, and Hurd's books [27,28] also provide pointers in these directions. In order to find more detailed guidance on day by day teaching methods we must turn to the teachers' guides of the modern curriculum development projects. Even before the advent of these projects independent authors had taken to adding a Teachers' Guide to their series of pupils books e.g. James [29], Branson [30], Bishop [31], Haggis [32], and this practice continues e.g. Dyke [33]. In the main however these guides are guides to content: results expected from practical work; interpretation; making apparatus; alternative experiments; possible snags etc. This is a useful function but there is rarely any guidance on method—a basic competence in teaching skills is assumed. Some American publishers have hit upon the technique of printing a Teachers' Edition in which the pupils edition is printed scaled down to half size (but still readable) leaving on each page ample room for guidance on content, apparatus and teaching method. An example of a traditional type Science course published in this way is the Modern Science series (for Grades 7-9) by Blanc, Fischler and Gardner [34], and among the newer projects the Science Curriculum Improvement Study has used the same technique. Some of the first generation curriculum projects, mainly in the specialist sciences have been lacking in guidance on teaching method, preferring to use the in-service briefing for this purpose. Since many teachers have to take up the teaching of these projects without briefing this is clearly not adequate and the teachers' guides to recent projects are more helpful.

A SPECTRUM OF TEACHING METHODS

Before proceeding to discuss new trends which have a particular bearing on integrated science it would be as well to outline the full spectrum of teaching methods currently in use in science teaching.

Band A	Textbook teaching
Band B	Chalk and Talk
Band C	Demonstration
Band D	Class activity
Band E	Individualised instruction

It should be clear that the spectrum does not consist of sharp lines of extreme purity, but rather of broad and overlapping bands, and that within the bands there are levels which merge into one another. In Band A the teaching may range from the teacher reading aloud from a textbook to directed and selective reading from many sources. Chalk and Talk methods range from the pure lecture, through question and answer to the most stimulating discussion, and Demonstration techniques range from the simple practical illustration of stated principles, through demonstration experiments whose conclusions are not given beforehand, carried out with student assistance, to genuine teacher-based enquiry where the students suggest and plan experiments and the teacher acts as a consultant and technician who supervises or carries out the experiment. There are similar levels of sophistication within the Class activity and Individualised instruction methods but since it is within these Bands that we will encounter the new trends I will not enter into any further detail for the moment.

The main feature of the spectrum is the trend to greater student involvement in the learning process. This is reflected in increasing student activity, the decreasing proportion of his time that a teacher spends with a class as a whole and the increasing proportion spent with small groups and individuals. The underlying trend is towards providing more opportunities for students individually to formulate and express ideas. In practice this generally means providing practical experience with equipment and materials, but this is only a means to an end. Practical activity in itself does not lead to understanding; it is thinking about it and attempting to put thoughts into words that really leads to understanding. The teacher seeks to achieve this by providing appropriate activities and by stimulating students to talk, and possibly to write, mainly by asking the right sorts of questions. The director of one recent project, having emphasised the need for direct hands-on experience of materials, claims that: "The key to the discovery method lies in the quality of the oral work" [35].

The trend away from class teaching does not necessarily imply the withdrawal of the teacher, but rather that he or she works more intimately with individual students either on their own or in small groups. The key issue here is how the teacher keeps the rest of the class actively involved in the lesson and goes on asking the right sorts of questions whilst engaged in individual work.

Two things should be clear about the spectrum that I have described. The first is that very few teachers operate purely within one Band of methods; indeed, the skilled teacher will use techniques drawn from several bands. Secondly the Bands must not be thought of as an absolute scale of values. Good demonstration teaching for example may be more effective and more stimulating than some rather formal class activity teaching, though we may consider that the latter, skilfully handled, has more to offer the individual than a regular diet of demonstration.

Class Activity Methods

Moving on now to those methods where students themselves are engaged in practical work, we can identify several different approaches.

D i Practical but not experimental. Usually exercises to verify what students have already been told. Emphasis on techniques; often associated with the dictation of notes.

D ii Simple experimental; genuine "lets find out" exercises; possibly rather trivial and often over-discussed and written up in unnecessary detail.

D iii Structured Discovery. Selected experiments designed to establish chosen principles; may be rather elaborate and often in strict sequence. Class discussion prior to and following the activity is a vital element.

D iv Directed Enquiry. A greater range of practical activities, simpler and less sequential. Questions may be posed by assignment sheets; discussion often within smaller groups.

D v Open Enquiry. Practical activity not pre-determined; exploration follows the student's growing interest and understanding. Teacher acts as consultant. Groups within the class may diverge.

Quite clearly these levels merge into one another. Where a practical approach to science teaching has been accepted the first two levels do not constitute any new trend. The remaining three approaches all warrant detailed discussion. Trends in integrated science teaching are to be found mainly in the Directed Enquiry and Open Enquiry approaches, but since the Directed Enquiry approach is partly a reaction to the Structured Discovery approach, the latter must be considered first.

STRUCTURED DISCOVERY

The structured discovery method is the approach adopted by most of the first generation curriculum development projects, particularly in the middle and upper forms of secondary schools (age 13+). It is often referred to as "stage managed Heurism", which acknowledges the objective of open-ended enquiry and of learning by discovery but simultaneously acknowledges the need for direction if a reasonable rate of progress is to be maintained. As a result experimental work is carefully planned and structured so as to lead the student to discover the appropriate principle, but at the same time to give the impression of genuine scientific enquiry. In the main these enquiries are conducted on a class basis with discussion playing a vital role in the process. In principle, in a preliminary discussion the teacher draws from the class suggestions for experiments (one or preferably more) to attack a given problem or to continue a study already embarked upon. After the experiment has been carried out the results are considered, weighed, debated and conclusions drawn. This technique of heuristic class discussion calls for highly skilled and on occasion inspired teaching. It is a skill which it is very difficult to teach or even to describe other than by showing a teacher in action. In practice teachers are often compelled to take a more direct line, to ensure that students understand exactly what they are supposed to be doing and why, and finally to establish that the point of the work has been clearly understood, even to the point of formulating a clear record which pupils can refer to later for examination purposes. This does not preclude a certain amount of genuine heuristic discussion at either end which represents a genuine advance on older methods.

A feature of this method at the secondary level is that the experiments tend to be rather elaborate and are structured in sequence, which may be necessary since they are dealing with fairly sophisticated concepts, but it does mean that a class has to move together through the scheme. The technique of class discussion is also open to question. Heuristic class discussion undoubtedly leads students to insights and discoveries; it is more questionable however whether these discoveries are shared or whether the first pupil who comes up with a creative suggestion, who first expresses the concept that the teacher is striving towards, does not preclude the rest of the class from making the same discovery which they might well have made for themselves given more time or other experiences. The discussion-practical-discussion method appears to work best with able pupils grouped in homogeneous but fairly competitive classes [36]. With classes containing a wider range of abilities even the most skilled teachers have difficulty in spreading the insights and discoveries around the class, or even in maintaining interest in the discussion stages. This may arise from the degree of abstraction involved in these discussions when patterns or theories are being formulated. Where the discussions are more closely related to concrete experience, or to social issues which directly affect the students these difficulties may be lessened. Some of the American elementary science programmes, namely the COPES [37], AAAS [38] and SCIS [39,42] programmes are described as structured and are used in mixed ability classes. The situations are less elaborate than in the secondary projects with more emphasis on concrete experience.

The Nuffield Combined Science Project recommends a good deal of structured discovery teaching. The Teachers' Guides [40] deal fully with each Activity in turn and give more guidance than is usual on how the discussion might be conducted, what points to emphasise and how the argument should be developed. This is done in support of specialist teachers venturing into unfamiliar territory. The West Indies Science Curriculum Improvement Project [41] in the Caribbean, catering for less experienced and untrained teachers also attempts to lead teachers stepwise through discussions.

In the structured discovery approach teachers use the time when students are experimenting to talk with individuals and small groups, to discuss the experiment as it proceeds, and they find this time very well spent. The heuristic discussion with the small group where each individual is able to contribute without having to speak out in the large group is of greater value to the student and is easier for the teacher; it is a fairly natural skill though not one that comes readily to teachers used to an authoritarian approach.

DIRECTED ENQUIRY

In the directed enquiry method the single, critical experiment of structured discovery is replaced by a number of shorter activities or experiences, which may or may not be sequential. The work is still structured in the sense that the teacher plans practical activities in advance, but he does not expect to predetermine every student's learning step by step. The activities are designed to build up understanding rather than to provide a single critical insight. The extended reasoning of the heuristic class discussion is replaced by individual reasoning or discussion in small groups, prompted either by worksheets, assignment cards, workbooks, textbooks, or directly by the teacher. The class discussion for review and summary has a part to play in this method, but a less important one; this tends to offend teachers who rely on summary and revision, who are humorously described in a SCIS publication [42] as suffering from "Lysiphocia—the fear of leaving loose ends". In general a class will tend to move together through the course but they may only come together at the end of a week or a fortnight rather than at the end of each lesson, and they need not all have completed all the activities.

CIRCUS TECHNIQUES

The use of multiple experiments lends itself to the Circus layout (also known as the stations technique or the pantopiric arrangement). In this arrangement several experiments are set out around the laboratory or classroom and the students move around them in any order. If there are only a few experiments to be carried out there may be several layouts of each. It is usual to have a few more stations than there are groups moving around the circus particularly if some of the stations take longer to complete than others. During a circus the teacher may wish to concentrate his attention on one or two stations where a practical skill has to be taught, or a hazard exists, or special questioning is called for. Alternatively he may be able to move around more freely. A circus may last one session or several depending on the complexity of the experiments which will usually be related to one another in some way (this distinguishes the circus from the common advanced physics practical arrangement). Typical circuses might consist of: simple energy conversions; forms of heat transfer; visible signs of chemical reactions; properties of metals; a range of skeletons; breathing experiments. Alternatively the circus may consist of a collection or exhibition (which might better be called a museum layout) e.g. of living and non-living things for classification; of bones; of corroded metals. The essential element of a circus is retained if the students have specific things to look for and to do (possibly based on a worksheet) at each station in the collection.

Using older teaching methods the various experiments in a circus would be taken individually, requiring many more sets of apparatus, so the circus is economical of apparatus, but it does call for considerably more effort in laying out. This is overcome to some extent by storage in kits, so that each station can be lifted whole from the shelf and laid out quickly. Expensive items like a meter or stopwatch cannot be left to stand idle in a stored kit, but a card to note that one is required is a quick reminder. One vital factor in the use of kits is that they should be checked before storage for missing items or breakages. The kit system is also used in primary schools, where students wishing to pursue specific topics can be directed to the appropriate storage point. Some projects have arranged that their materials can be supplied in kit form, e.g. ESS, and this is valuable where a school does not have a regular apparatus allocation or supporting staff. Inexpensive kits have been developed by the IBECC (Brazil) project [43]. The directed enquiry method still requires class sets of certain items of equipment e.g. circuit boards for electrical experiments, where there are several activities all based upon the same equipment. These could be used as a circus with different activities at each point, or used only by one group which works through the activities in the same order as other groups.

In order that the teacher may spend time with individuals and small groups some form of independent direction is required for the rest of the class which provides appropriate instructions and asks the questions which will help the student to reason. In simple cases this may be written on the blackboard, or an overhead transparency displayed on a screen. When more reading is involved there is a choice of consumable (provided for and used up by one student) or non-consumable (can be used over and over again) material. The non-consumable may be a book e.g. Experimental Science [33], a booklet e.g. the Activities of Nuffield Combined Science, or an assignment card which is set out with each experiment or carried around by the student e.g. JSSP [44]. These have the merit of being permanent or semi-permanent and the disadvantage that the student must write a good deal in his record book to make an intelligible record. The consumable assignment may be a workbook e.g. those of the Nigerian projects [45,46] or a worksheet e.g. the Science Worksheets [47] of the Scottish Integrated Science Project [48]. These have the advantage of building up to a full record of what has been accomplished (with the assistance of occasional summaries), worksheets having greater flexibility than workbooks. The Scottish Integrated project provides an interesting comparison between the consumable and non-consumable approach having available as alternatives both a published set of worksheets and a text book [49].

The commercially published worksheet has the advantage of professional layout and attractive appearance; the home-made duplicated worksheet can be more specifically written for the available equipment and to the known abilities, interests and existing knowledge of the students. Some very sound advice on worksheet production is given in the Teachers' Guide to the Nuffield Secondary Science project [50] which uses them extensively; some of the important points are: they should be visually attractive, with a good layout for both assignment and response, not too wordy (diagrams and flow diagrams may help), but written in language that the students will understand. The essence of a worksheet is that it poses questions; instructions may also be included, but detailed instructions for a particular activity may be better written on a card which remains at that station. A good test of what directions to include in the worksheet is whether the completed sheet makes sense when referred to some time later.

Problems in worksheet production include the need for good duplicating facilities, the quantity of paper required (one school known to the author uses 15,000 sheets of paper per term for 300 pupils), the storage of sheets prior to use, the storage of stencils for further use. Problems in using worksheets include students' unwillingness to read properly before starting work, which may call for an initial reading and discussion; different rates of working, which may be catered for by including additional activities or more demanding exercises for fast workers; filing for reference, which requires some sort of holding device rather than loose storage in envelopes. Non-readers or poor readers may have difficulty in coping with worksheets. Townsend [51] has described a method of presenting assignments on audio tapes, sometimes with associated visual material. He claims that this technique improves the students' motivation to work, but that once the novelty effect has worn off reasonably competent readers will revert to worksheets.

OPEN ENQUIRY

The method of Open Enquiry is so far almost exclusively associated with the primary (elementary) school. The essence of open enquiry is that the student's activity is not pre-determined by the teacher but follows the natural development of the student's enquiry starting from a point of interest which either arises spontaneously or is contrived by the teacher. The teacher has to anticipate the development of the enquiry so that she may provide appropriate support in terms of materials and resources, ask appropriate questions and provide information or direct students to sources of information. A number of case studies are available showing how such work develops in British schools [52,53,54] starting from a single point of interest and branching out in all directions, integrating the science work with other activities. The Teachers' Guides to the Nuffield Junior Science Project provide an excellent account of the philosophy of this approach and guidance on simple apparatus and on the care of plants and animals in the classroom. The Guides however lack

(a) clear objectives by which the teacher may assess whether her pupils are making progress,
(b) suggestions for specific activities (though this has been made up in part by an independent publication of the project staff [55].
(c) guidance for the teacher, who rarely has a science background, on the scientific aspects of enquiry.

Science 5/13 (U.K.) [56], Elementary Science Study (U.S.A.) [57] and the African Primary Science Program [58] are parallel projects using the open enquiry approach, all based on Units. Each Unit typically consists of a teacher's guide, suggesting starting points for enquiry and showing how the work is likely to develop so that the teacher may anticipate and plan accordingly. The subtlety with which the teacher uses this material decides whether the work remains open enquiry or becomes directed enquiry.

It could be argued that where the teacher controls and guides the work to this extent, and is also working towards educational objectives which may be set out in some detail, then the work is in fact highly structured and not at all open enquiry. It should be clear that I am using the term open enquiry in a special sense where pupils are allowed and encouraged to develop their own enquiry rather than stick to pre-arranged activities. Where the enquiry falters the teacher is at hand to stimulate, to guide and even to suggest further activity where necessary. Open enquiry is not by any means independent enquiry, but is best regarded as work done in collaboration with the teacher.

Another project, which has already been quoted on the importance of the quality of the oral work in discovery methods [36] includes key questions and discussion leaders in assignment booklets based on similar Units; many of the questions are open, allowing the student to seek answers in his own fashion, and the student is encouraged to go beyond the immediate answers. This uses directed enquiry to launch open enquiry. A whole class may embark on a topic and soon start pursuing different lines of study which eventually come together under the teacher's management as a unified project. On the other hand pupils may proceed independently following enquiries which the teacher judges will contribute to their overall educational development. This is typical of modern primary school practice but it requires skilled teaching to hold in mind basic objectives for each individual and simultaneously to retain the scientific element of the enquiry. Most teachers would be happy to start using the Unit suggestion in a directed enquiry fashion, allowing some open enquiry to develop spontaneously as indeed it often does in both structured discovery and directed enquiry methods.

The use of open enquiry methods in secondary schools has in the past been restricted to such spontaneous interludes, which are usually short-lived, and to occasional project work. Science 5/13 is being tested in the lower forms of some British secondary schools, where a number of problems are encountered. The fixed length of the lessons, the time elapsing between science lessons, the infrequent visits to the laboratory and the frequent change of teacher from subject to subject all tend to break the continuity required in open enquiry. This is being tackled in some secondary and many middle schools by greater integration of subjects and semi-specialist teaching. The increasing sophistication of students' enquiries inevitably puts pressure on space, equipment and materials. The growing literature on science-technology work in schools [59] suggests that this difficulty may be overcome, but not yet on a basis whereby it may form a normal part of the curriculum for all pupils. Fears that open enquiry would not lay sound foundations for subsequent work appear to be groundless.

INDIVIDUALISED INSTRUCTION

It is a short step in principle from the worksheet-directed approach to an individualised programme, where students work at their own pace from prepared programmes. In the context of modern activity based science teaching the conventional programmed learning approach via teaching machine or printed programme is reminiscent of some of the dullest and most formal text book teaching; nevertheless it has superficial attractions in areas of teacher shortage and is fairly easy to test under classroom conditions so that a good many studies have been reported, most of them involving short programmes [60,61,62,63,64]. The current list of programmes available in print in the U.K. [65] lists 386 science programmes of various lengths, on various subjects at all levels. A more promising approach is the programme with built in practical activity. Bosworth has devised a course [66,67,68] of laboratory programmes; a programme may involve from 2 to 14 hours work, 8 hours being the average length; the programmes may be taken in any sequence so that at any one time most of them may be in use, which means that almost any piece of apparatus may be required at any time and the distribution problem is solved by packing individual kits for parts of programmes. The Bosworth scheme is based mainly on linear programming, but other individualised programmes use worksheets or workcards to direct the work which are less dependent on programming techniques. Lunetta and Dyrli [69] have surveyed individualised instruction in science curricula in the United States without finding many instances to report; Burkman [70] describes the intermediate Science Curriculum Study, grades 7-9, [71] as an individualised approach to science instruction, and DeRose [72,73] has used similar approaches at Marple Newtown High School. Reid and Booth have investigated independent learning in biology in the first two secondary years and have discussed the results of their investigations fully in a number of articles [74,75,76]; their materials have been published as a series of books entitled Biology for the Individual [77]. They find that independent learning is successful if used occasionally for appropriate topics but do not recommend it as the sole method of teaching. This work was sponsored by the Nuffield Resources for Learning Project; L.C. Taylor, its

Director has discussed independent and resource based learning [78,79]; a third year science course has been developed and Taylor quotes a figure of 21 hours work to produce one hour of useable material. A Handbook on Independent Learning is to be published, and the Teachers' Guide to the Biology for the Individual series provides a good deal of practical advice on method. The Junior Secondary Science Project (Victoria, Australia) [44] has produced eighteen Units for a two year course. Each Unit consists of workcards, reading material, research activities (optional) and pupil marked tests. This material can be used for individual work, but many teachers find a need to work in some class teaching and discussion. The Teachers' Guides to each Unit are written with the teacher who has a limited background in science in mind.

The major objection to completely individualised instruction appears to be the loss of the social element involved in group discussion. In later life after all most problems are worked out by discussion in groups. The further isolation involved in computer based or computer aided instruction [80,81] is not likely to affect very many pupils in the near future, but calls for critical appraisal.

RESOURCES FOR INTEGRATED SCIENCE TEACHING

One of the main factors influencing class activity methods generally is the size of the teaching group. In secondary schools in Scotland the average group is twenty, in Wales thirty, in the Caribbean forty, and elsewhere it may be even higher. Teachers find it possible to organise some activity even with large groups. The best small group size is often assumed to be two but a group of three may promote better discussion; it is difficult for more than three to work together at a bench though four may work round a table. The availability of laboratories and apparatus is a perennial problem, but the partial availability of laboratory space for two lessons out of three, say, is often more perplexing. The common practice of two periods practical followed by one of "theory" where the practical is discussed and written up is unsatisfactory, teachers often having to spend most of their time reviving half forgotten impressions. It is important that recording should be done at the time of the activity; worksheets and workbooks help to ensure that this is so. This may be partly resolved by equipping a classroom with flat tables rather than with desks; this allows for simple activities not requiring services or too much circulation. Schools with no laboratories, and this includes most elementary schools, may be able to equip classrooms with elementary services [82]. Adequate storage space, which can be securely locked but which is easily accessible, is of the utmost importance. Modern school laboratories are built with fewer fixed units; the services may be found only at the walls or at fixed pedestals, and moveable tables or benches can be arranged around them. This is particularly appropriate for integrated science, and is very well suited to circus techniques where different layouts can be planned to suit different types of circuses. The moveable units can even be arranged in rows facing the teacher if necessary. The demonstration bench is now often omitted, freeing a great deal of space for class activity, or if retained it becomes another student bench on most occasions. When the teacher wishes to demonstrate he may set up one of the moveable units in a convenient place, often centrally rather than at the end of a long laboratory which is where demonstration benches are often placed.

The increasing stress on the environment in integrated science courses emphasises the possibility of work outdoors, and much work which is normally done in laboratories can be equally well done outdoors, though frequent rainfall or excessive heat or cold may limit these possibilities. Most teachers have to cope with less laboratory time than they would wish and with shortages of equipment, and have to use a great deal of ingenuity in devising practical scientific activities which can be carried out with the facilities available. Curriculum developers must also be challenged not to ignore these practical limitations.

Another factor influencing activity methods is the mode of teaching adopted by other colleagues. In the secondary school the best policy would appear to be to use the selected method as soon as a student enters the first form, so that he accepts that, however other subjects are taught, this is how science is learnt.

One of the most open questions in integrated science teaching today is the role of the textbook and other printed material. On the one hand we have a large number of integrated science textbook series available, ranging from the pure workbook with little or no text (though diagrams and illustrations may be partly a substitute) to the textbook with practical activities. I have listed a number of text series which are published in Britain (ignoring the fact that several of them originate in Australia and New Zealand) in order of increasing text content; the titles themselves are an interesting reflection of the desire to dissociate the approach from the older one of General Science.

Experimental Science (Dyke) [33], Doing and Thinking (Buttle) [83], Experimental Science for Tropical Schools (Bishop) [31], Junior Science (Southgate and Folivi) [84], Science for the Seventies (Mee et al) [49], Finding Out in Science (Haggis) [32], Science Through Experiment (Shires et al) [85], Science Makes Sense (Buckley et al) [86], A Foundation Course in Science (Schofield et al) [87], In Search of Science (Bingham et al) [88], Natural Science (Pergamon) [89].

Most of these series are intended for the lower secondary school, some for the middle school (age 14-16), and there are considerable differences in content and sophistication. One of the most interesting features is how the various authors integrate text and experiment. In the pure workbook there is little text e.g. Dyke, so that it cannot serve as a reference book. In some of the books e.g. Junior Science, results almost always follow the experimental details, which limits the experimental nature of the work considerably, whereas in others e.g. Science Makes Sense, experiments are integrated into the text but the results are not given so that the text makes little continuous sense except to the teacher who knows what should happen. Elsewhere e.g. in the Foundation Course in Science, text and practical work are printed separately and the experimental results can be found in the text after a bit of searching so that it serves both as a practical book and a reference book. Some authors, without publishing the results of individual experiments, include summaries of the most important points covered.

On the other hand few of the early integrated science curriculum projects have produced text material for students' reading, devoting most of their attention to practical activities. The primary school projects emphasise the importance of consulting reference books and background reading of all types, and there is a wealth of such material available. Few secondary schools however have the type of class library that exists in primary schools. This is unfortunate since science activities are known to stimulate reading in primary schools. The Junior Secondary Science Project in Australia [44] and the Australian Science Education Project [10] both make use of library assignments, and the Schools Council Integrated Science Project [90], developing an integrated course for able 13-16 year olds is laying a fresh and welcome emphasis on reading about science and discussing its social implications, as is the Agriculture as Environmental Science Project in Israel [91]. The techniques of initiating and sustaining such discussions without resorting to indoctrination are very difficult: students must be provided with genuine resource material or case study material upon which to base discussion. This is certainly one of the newer and more important trends in integrated science teaching. There is a conspicuous lack, in most countries, of books or publications which demonstrate the importance of science in the everyday life, health, industry, agriculture and natural history of the country, and which relate the work done by students in school to their future role as citizens.

I have devoted little attention to the use of visual aids in teaching, but a wide variety of such aids is available. The Australian National Science Curriculum Materials Centre has produced overhead projector transparencies, slide sets, stereo prints and viewers, single concept loop films, audio tapes as well as core books, worksheets and test materials; these are intended to be used with any science curriculum rather than as an independent approach [92]. Such material is also available from other curriculum projects and independent publishers. The UNESCO Handbook for Physics Teachers [93] has a valuable and up-to-date chapter on the use of visual aids. The important consideration in the use of any visual aid or resource material is that it is used for some specific and well defined purpose rather than as mere entertainment. The contribution of radio and educational television to integrated science teaching has not been fully considered. By definition these techniques are remote and do not lend themselves to activity methods unless the class teacher's role is carefully planned and carried out [94]. In the main the initiative has come in the past from the broadcasting end [95]. Ball describes in detail the use of radio in science teaching, mainly in Britain and Kenya [96] and attempts are being made to plan major televised contributions to science curricula in Barbados, Israel and elsewhere. The forthcoming UNESCO volume on Educational Technology and Science deals much more fully with recent development in this field [97].

INTRODUCING INTEGRATED SCIENCE

The problems of introducing integrated science into primary (or elementary) schools and into secondary schools are different in kind. In the former there is little tradition of science teaching and teachers have few, if any, qualifications in science. As a result teachers have little appreciation of what science teaching has to offer at this level and are fearful of committing themselves to it. Since the primary science curriculum materials have been developed for precisely these conditions the most important requirement is to overcome this initial hesitation. This requires the support and encouragement of the head teacher, who will have to provide materials and to accept changes in classroom practice, and also of at least one experienced colleague either from the advisory services or teachers' college or from another school. A small group attempting to introduce new curriculum materials in their own schools and meeting together to discuss progress can provide mutual support, but the key to the situation is that they should know that these materials have been used successfully elsewhere and that they should be able to consult with some person who has experienced such success. Eventually it is to be hoped that the initial training of teachers will serve the same purpose, but until there are a number of schools using these methods where students can practice it is hardly to be expected that new teachers will develop the appropriate skills.

In the secondary school where science is an accepted part of the curriculum the problems are rather different:

(a) some teachers may have little experience of any form of practical teaching, or even of methods which involve discussion with students or questioning other than to test recall;

(b) some teachers may be unwilling to teach aspects of science other than their own specialism, often on the grounds that they are not competent to do so and that this would be unfair to students;

(c) the number of teachers who will be involved in integrated science teaching, the several teaching areas and the amount of equipment involved pose greater organisational problems than when the specialist subjects were taught independently.

The answer to each of these questions lies in collaboration and cooperation. Where there are several parallel classes all involved in practical activity in several laboratories it is not possible for each teacher to plan his or her own course and to demand the appropriate equipment at short notice; there must be a common policy and a planned programme of work. The directed enquiry approach with kits of apparatus and worksheets lends itself to shared planning and preparation. The work in a particular topic area may be planned and the worksheets written by one or two teachers, possibly specialists in that area, and taught by all members of the team to parallel classes. This relieves the non specialist of the burden of planning and assures him that further assistance is at hand. There are strong reasons in favour of an integrated science course being taught by one person, but if the teachers concerned are still dubious it may be possible for two teachers to teach two parallel classes, and to exchange classes for the sections that pose problems. An inexperienced teacher may also be paired with an experienced colleague in a similar way.

If many worksheets and many writers are involved it is as well to have one member of the team allocated the responsibility of coordinating the production. Where a number of parallel classes are being taught simultaneously the team leader must arrange different routes for different classes so that there is no overlap in apparatus requirements. Good organisation in storing and distributing apparatus and worksheets is essential and is hardly possible without ancillary help.

The problem of the inexperienced or untrained teacher is also relieved by shared planning and preparation. The directed enquiry approach requires a great deal of planning which would be an impossible burden for an inexperienced teacher, but once the worksheets have been prepared and the apparatus requirements are known the teaching situation is far easier than the structured discovery or demonstration approaches and more rewarding for the young teacher in terms of confidence gained .and skills developed. Even if there are no experienced colleagues to do the preparation, the curriculum materials themselves may provide the required support e.g. the Scottish worksheets and the Nigerian workbooks. The WISCIP materials in Trinidad [41] were designed primarily to support inexperienced teachers working without experienced colleagues to guide them, and as such provide more detail on the routine aspects of lesson management than is usual.

Peacock [98] describes an exercise in team teaching in the Scottish Integrated Science course, with key lessons given to over one hundred pupils followed by group lessons taken by six teachers. The aims of the key lesson were to stimulate interest in a new topic, to economise on the time required to set up large demonstration experiments, and to give a lead to colleagues; there is no saving of staff time. This might be termed standard team teaching but less formal team work seems to be far more common [99]. The SCISP Teacher's Handbook [100] includes case studies from three schools illustrating different methods of grouping and of staff collaboration. It is to be hoped that many more such examples will be published. SCISP has prepared a slide-tape presentation entitled 'Integrated Science in Action' which shows team cooperation in action [101]. At the simplest level, when two or more teachers are teaching classes in parallel, regular discussions of progress and of plans for forthcoming sections are invaluable especially for new colleagues. Many science departments are able to timetable one period weekly for such discussions. A recent development in school building is to design large working areas where as many as six classes may work simultaneously with small adjacent discussion areas; one can see how this might simplify the distribution of apparatus, a topic area being set out in the same part of the laboratory on all occasions. It would also seem to be helpful to have the whole team in operation at the same time so that it would be quite natural to refer a student to a colleague for some particular piece of information or expertise.

May I conclude by expressing the hope that one of the most significant results of integrated science teaching should be the growth of shared responsibility between colleagues as well as between teacher and student.

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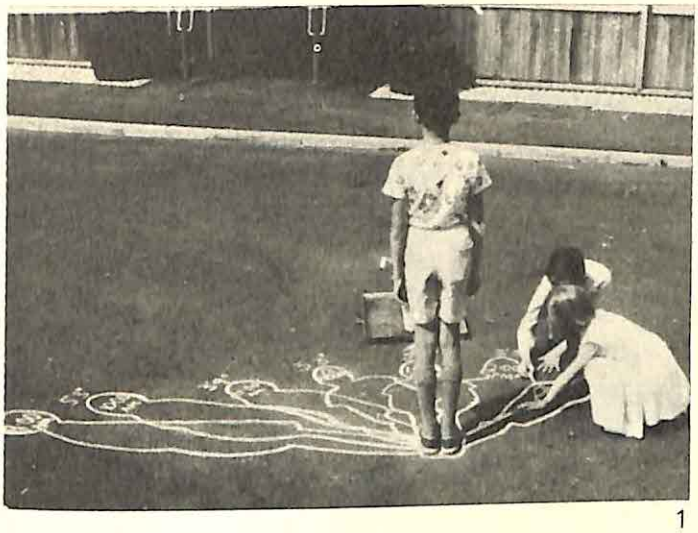

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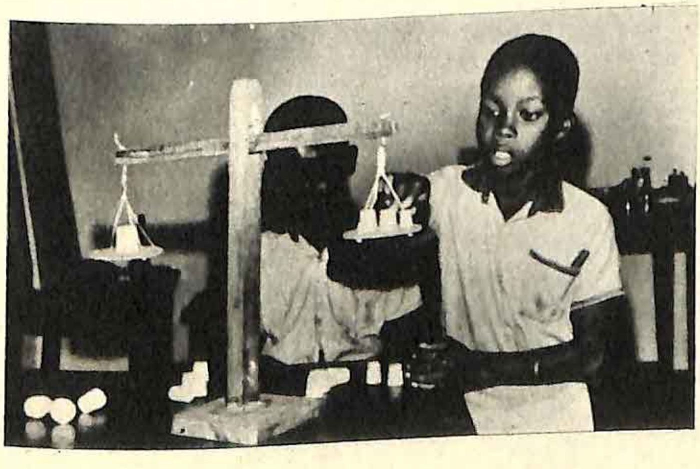

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Chapter 5

INTEGRATED SCIENCE IN TERTIARY EDUCATION

L. G. Dale
Australian Science Education Project

Summary

Emphasis in tertiary studies is changing from the pursuit of knowledge for its own sake to assisting man to understand and solve the problems of contemporary society.

Studies in the sciences have become increasingly more specialized. In order to provide for wider background in science, integrated science courses have been introduced in many tertiary institutions throughout the world. Some of the courses are designed for non-science students. Others are designed for science students at undergraduate and post-graduate levels.

Various procedures for integration have been adopted. Among these, the unified topic approach appears to lead to the most coherent courses.

Although there is a significant trend towards integration of the sciences there is a need to maintain concurrent specialist courses. The conflict of interests between the specialists and the integrators, combined with resistance to change in institutions organized for specialist training, are two of the major obstacles in the path of integration.

Where the functions and goals of tertiary institutions have been clearly defined, the need for integrated science studies has become apparent, to equip students to operate as intelligent citizens in modern society.

The problems of contemporary society are pervasive and their solution requires the co-operative effort of experts in many fields. Conversely, our accumulated knowledge, much of which is not related to societal problems, is increasing at an alarming rate, and society, through its agents the tertiary educational institutions, is producing experts in increasingly narrow fields. This chapter is an attempt to show what is being done in tertiary institutions to resolve the conflict of specialization versus a wider view, in the field of science.

Emphases in tertiary studies

The roles of universities in society have changed a great deal since the first institutions were established in the twelfth century. Early universities consisted of groups of students and scholars, separated from the rest of society, working together for the advancement of learning, with strong beliefs in the unity of knowledge. In the fifteenth and sixteenth centuries, tertiary institutions became wider in type and in scope. They became involved in the preparation of scholars for professional careers in law, medicine and theology, in particular. Developments in new fields of knowledge, particularly in science, led to differentiation of the curriculum. During the nineteenth century, specialization into "subjects" developed further, breaking down the original concept of the unity of knowledge and leading, late in the century, to the establishment of major subject "disciplines" in the arts, natural sciences and social sciences. Parallel with the segregation of knowledge into subjects was increased attention to education for the professions.

In this century, the process of change has accelerated. The rapid increase of accumulated knowledge, the multiplication of student populations and the effects of advances in science and technology, especially have all had their impact. The numbers and types of tertiary institutions have increased many-fold. In the effort to extend knowledge, specialization has become increasingly narrow. In attempting to meet the demands of new fields of human endeavour, previously segregated areas of study have been joined in new combinations. The emphasis of tertiary institutions is changing from one of producing and distributing knowledge, largely in isolation from society as a whole, to one in which the values and needs of society are of prime importance. The modern tertiary institution is now seen by many as an agent for transmission of culture and a means of effecting changes in society. At the least, a university is expected to reflect the changes that have taken place in society. The change in emphasis that is now taking place has led to conflict between the 'traditionalists', and the 'progressives'. The 'traditionalists' want to preserve high standards of scholarship in subject disciplines and pursue knowledge for its own sake. The 'progressives' want tertiary institutions to meet the challenges and needs of modern society. Older universities, in particular, have an administrative structure designed to perpetuate and promote subject disciplines. It is when this structure has been challenged that conflict has arisen.

It is now apparent that many of the problems of modern tertiary institutions, and of universities in particular, are due to modes of organization which are out of step with the requirements and needs of modern society. Universities, like schools, exhibit a strong reluctance and, frequently, active opposition to change.

Changes in tertiary science courses

Science, as a field of study, has gathered impetus in its infiltration of the tertiary education scene to the point where it now dominates. There are more tertiary institutions devoted to the study of science and its applications than to all other fields of study put together. Courses in science and science-based areas of study out-number all other courses and take the lion's share of the budget of most institutions. There are many indications, however, that the type of science education provided by the older institutions, in particular, is no longer needed to the extent it was needed in the past. The anomaly of the science Ph.D. unable to find employment in the area for which he has been trained has recently appeared and is increasing in frequency of occurrence. The university reaction has, for the most part, been one of concern, and in some instances has led to a desire for re-examination of the purposes of university education. This desire has been reinforced by similar demands by students.

The conflict that has arisen is between the demands of science and technology and the demands of society as a whole. Science and technology require increasing specialization and rapid extension of knowledge and skills. Society is acutely aware of problems created by the blind onward rush of technology and is demanding a more rational approach and a wider perspective of education. Some of the resources that are being used to maintain the impetus of science and technology could be diverted to strengthen the position of society by attention to present-day problems.

Since universities are regarded as the senior tertiary institutions, and since it is possible to discuss most of the problems and trends of tertiary level science teaching in the context of university courses and programs, the remainder of this chapter will refer mostly to what is happening at universities.

Forty years ago, pure science in most universities consisted almost entirely of the basic subjects, physics (which still clung to its old title of Natural Philosophy in some institutions), chemistry, botany, zoology and geology, which had evolved as separate disciplines. Most institutions contained schools of medicine and engineering, among others, and students in these schools were required to take one or two years of study in selected science subjects. Two kinds of change evolved. At third and fourth year levels and in post-graduate studies, subjects became increasingly specialized. Instead of selecting "third-year physics" as the only physics study offered, the student was able to choose from a veritable smorgasbord of subdivisions of physics, mostly highly specialized and clearly segregated from the rest. Instead of offering one first-year subject in physics, for example, a number of courses appeared at first year level, each tailored to suit better the total program to be followed by the student. Simultaneously, there was a move in the opposite direction. Combinations of subjects, such as biology, geochemistry, astrophysics, and biochemistry appeared. More recently, groups of subject areas have been combined into subjects such as physical science, biomolecular science and materials science.

Pressures from two opposing directions have provided the stimulus for change. On the one hand, the rapid growth of scientific knowledge has required increasing specialization. On the other hand, the need for many professional people to be knowledgeable in several areas, the occurrence of problems that can be solved only by co-ordination of research in several specialties, and the demands of students, particularly non-science students, for an understanding of the role of science in modern society, have provided strong pressure for less specialization and the presentation of wider views of science.

In the late 1950s and the 1960s, university scholars led the movement to improve science teaching in secondary schools. Initially, their solution was to teach the "fundamentals" of the subjects (which were usually referred to as "disciplines") and hence it might be thought more people would become scientifically literate and the universities would be able to produce better scientists and technologists. New text books and procedures were developed and introduced into schools. These included materials produced by the Physical Sciences Study Committee (PSSC), CHEM Study, the Chemical Systems Project (CBA Chemistry) and the Biological Sciences Curriculum Study (BSCS Biology). But over a period of several years the schools gradually reacted against the acadėmic approach and the specialized nature of the new science courses. The immediate solution–integrated science–became, and still is, the popular solution. The move towards integration of the sciences was an attempt to restore unity and to give students a view of science as a field of endeavour, rather than a narrow view of one or two subjects in the total field. The latest development in science teaching at the secondary level is the move to make science more relevant to students as members of a developing society. This requires the inclusion of aspects of psychology, sociology, anthropology, art, and other subject areas that may have little apparent relation to science. At the extreme, such studies have no subject boundaries.

To some extent, the developments in secondary school science courses have applied pressure on the universities and have led to a re-thinking of the purposes of university education. This feedback effect is more apparent in USA and Australia than in the United Kingdom, possibly in inverse relationship to the degree of university domination of secondary school curricula.

An unexpected effect of the increasing involvement of university teachers in the in-service training of schoolteachers has been the pressure on the former to reconsider their assumptions. The universities stand to gain as much as the schools from co-operative work. It appears, however, that so far most of the pressure for change has come from sources other than the secondary schools. In some respects, university curricula are evolving more rapidly than secondary school curricula. This is more apparent in new universities (and other tertiary institutions) where radical departures from traditional practice are apparent.

Specialized versus general science studies

The major departures from traditional university practice are in two areas—the preparation of students for future professional careers and the general education of non-science students. Within the last three years, there have been indications of a change of emphasis from "specialist" to "generalist" education. Careers for which "generalist" education is seen to be more appropriate include teaching, careers in industry, scientific journalism, town planning, conservation, science-related management, administration of science-related organizations, community health, publishing and the public service.

This change is most evident in the British Polytechnics and Colleges of Technology, Hutchings [1], in his article published in May 1972, listed 13 Polytechnics and Colleges of Technology at which "approved inter-disciplinary degrees" are offered. The main areas being offered in combination with science are history and philosophy of science, economics, marketing or management or business administration, industrial studies, mathematics and computer studies. Some examples of courses offered follow.

Lanchester Polytechnic	Applied physics with management studies or education and the Technological Society.
North East London Polytechnic	Applied biology with business and management studies.
Sunderland Polytechnic	Choice of subjects from biology, chemistry, economics, geology, maths, physics, physiology and computer studies.
Trent Polytechnic	Applied chemistry with industrial administration and computer studies.

Information from the Council for National Academic Awards lists 18 courses and programs approved since 1971, five of which were described as "integrated", four as "multi disciplinary" and nine as "combined". Examples follow.

Integrated	Biomolecular Science	Portsmouth Polytechnic
	Physical Sciences	Plymouth Polytechnic
Multidisciplinary	Science	Ulster College
	Science and Mathematics	Sheffield Polytechnic
Combined	Life Sciences	North East London Polytechnic
	Materials Science	Thames Polytechnic

Universities are making moves in the same direction. "Generalist" studies known to the author in Great Britain, include Integrated Science Studies at the University of Aston, courses at Sussex University, Integrated Physical Science at the University of Keele, and Integrated Science at Stirling University. In Australia, courses are offered at the Canberra College of Advanced Education, and the University of New England. Other generalist courses are offered at the Centre for University Studies of Regional Development, University of Tours (France), the University of Wisconsin (USA), and Hacetteppe University (Turkey). Some of the courses in environment education described by Aldrich and Kormondy in their report for the Commission in Undergraduate Education in the Biological Sciences [2] would also fit into this category.

One example of "generalist" courses is the Integrated Science Studies course at the University of Aston in Birmingham. The following information is taken from the brochure describing the course.

> "It aims to provide a science-based general education which should bridge the gap between the specialist scientist and society at large. It is intended to prepare students for careers in which a general science background is helpful—such as some branches of

> public service, administration, technical journalism and publishing, as well as many other occupations requiring an understanding of how scientists work and the way in which their work affects society and is controlled by it."

The course is designed to be interdisciplinary and interfaculty and to give a thorough knowledge of common factors in the methods used by Pure Science, Applied Science and Social Science. The relevance and limitations of all these disciplines in the solution of real problems will be studied in detail.

The need for this type of broad-based course is considered to be growing in today's world. Professor Ernest Braun of Aston's Department of Physics, who is chairman of the academic advisory board for Integrated Science Studies, explains why:

> "It is no longer sufficient to look at problems from a narrow technical point of view. In addition to science and engineering specialists, we require a growing number of graduates with a broad knowledge of the scope and methods of science and a thorough grasp of its interaction with society. These are the new science generalists–the people who will interpret scientific problems to society at large, and who will hold together the various strands.
>
> Another closely related purpose of the course is to provide an opportunity for a general education of people with mixed A levels. An increasing number of sixth formers are now taking one or two science subjects, plus an arts A level. These are people who at school have taken an interest in science, but do not wish to become scientists.
>
> In the future there will be a growing number of people required to look into the social and economic consequences of taking certain technological courses of action. We shall require people who will be able to assimilate the information of scientific experts and balance it against the needs of society. Equally, we need people to evaluate the rival claims of scientists for the solution of given problems, in the light of economic and social factors.
>
> Integrated Science Studies should provide a better qualification for these tasks than almost any other existing course."

An example of a university department established to conduct "generalist" courses is the Resource Science Center at the University of British Columbia. The Resource Science Center was established in 1968 and joined the activities of elements of Agriculture, Architecture, Community and Regional Planning, Commerce Ecology, Resource Economics, Geography and Forestry. Emphasis primarily is on graduate training and research, aiming to develop interaction between the various disciplines concerned, to stimulate truly interdisciplinary research, and to introduce new techniques of mathematical analysis and synthesis that have emerged from the development of computers. The computer provides the focus to stimulate co-operation between the disciplines.

Science for non-science students

Many of the innovations concerned with combinations of subject areas are directed towards the general education of non-science students. Many of these innovations are in the field of "environmental education" and appear in tertiary institutions in USA. A review of the developments in this field was published by the Commission in Undergraduate Education in the Biological Sciences, in 1972. [2]

The move towards environmental education is one response to strong criticism of American tertiary institutions. Some of the courses and programs have been operating for many years but most have been introduced within the last three years. The courses range from first year undergraduate to postgraduate. Some lead to degrees; most do not. What they have in common is an "interdisciplinary" structure in that each course draws on knowledge from several fields of study.

The CUEBS publication [2] describes courses at 15 institutions in USA, including goals of the program, how it evolved, relation to other activities in the institution, problems encountered and likely developments. Many of the programs are suitable for non-science students. One example, is the set of courses available at the Williams College Center for Environmental Studies, Williamstown, Massachusetts. The College was founded in 1967, "to provide students with a basic understanding of the environmental problems facing modern societies as they are perceived by different disciplines in the natural and physical sciences, the social sciences and the humanities." [2, p.57] The students are required to fit their environmental courses into the courses that they have decided to major in. They must take a junior level course entitled "Perspectives on Environmental Analysis" which makes explicit the complex, interdisciplinary nature of environmental issues and problems. They must also take one senior course dealing with environmental topics in respective major fields and a senior course entitled "Environmental Planning and Policy".

The development of courses in environmental education is only part of a much wider effort to increase the scientific literacy of the general student population. The desire to present the non-science student with a wide view of science has resulted in courses in many tertiary institutions throughout the world. For many years, programs for teachers have included a mixture of science subjects, including history and philosophy of science. Professor V. Lawrence Parsegian, Rensselaer Professor at the Rensselaer Polytechnic Institute, has devoted much of his time in recent years to studies that inter-relate science, technology and humanities in a social context. His first major project, which began in 1965, produced two text books for a two-year program for non-science students "Introduction To Natural Science". The two books "The Physical Sciences [3] and "The Life Sciences" [4] were designed so that the first year course could be taken by a physical scientist and the second year by a biologist. Pilot trials were conducted and led to the interesting conclusion that "student learning does not follow the logic of older minds" and, hence, "the project has been guided at least as much by pilot class reaction . . . as by faculty opinion." [5] Parsegian's current project is titled "Building Educational Bridges Between Science and the Humanities and Fine Arts". The aim is to prepare a program of studies "suitable for college students of all professional interests" [6]. Other university courses for non-science students, known to the author, are conducted at Simon Bolivar University (Venezuela), Open University (UK), University of California, Columbia Teachers College, Evergreen State College, State University of New York, Hofstra University, University of Rochester, University of Maryland (USA), and Macquarie University (Australia).

Further information about science courses for non-science students can be obtained from the Eighth Report of the International Clearinghouse of Science and Mathematics Curriculum Developments [7], the proceedings of the Boulder conference on physics for non-science majors [8], Science in the College Curriculum" by Robert Hoopes [9], the CUEBS publication [2], the Newman Report [10], the Commission on Science Education Review "Science for Society" [11], and the NSF publication "Programs for Improving Education In the Environmental Sciences" [12].

Integrated Science for Science Students

Clarke [13], in presenting the case for an integrated tertiary science course, asked "Why are all the really good tertiary science courses for non-science students?" Much more attention has been given to wide-based courses for non-science students but some such courses for science students have been introduced. At the undergraduate level, most of these are short courses at first or second year level but some continue to degree level. Some of those designed as professional career training have been described above.

The "Integrated Science Studies" program planned by the University of Aston begins with separate sciences in the first year and develops into "integrated science proper" in second and third years. "Integrated Physical Science", planned for the University of Keele, has an "integrated" first year and involves selection among separate sciences, mathematics and humanities in the second and third years. This program, like others of this type, aims to give a broad base to academic studies and to demonstrate inter-relationships and the unity of science. "Integrated Science", a three-year program at the University of Stirling [14], is integrated at all levels, the third year being devoted to the study of topics, such as Pollution and Its Control, which require knowledge from several subject areas. Science studies at the University of Sussex [15] are organized in four schools–Applied Sciences, Biological Sciences, Mathematical and Physical Sciences and Molecular Sciences. Each school has a "multi disciplinary" structure in that a range of subjects, including sciences, economics, psychology, mathematics, and sociology, is taught. The structure provides opportunity for the introduction of studies of an "integrated" nature and groups in the university are looking at the question of introducing integrated courses but no definite proposals have been made to date.

In 1968, the Dainton report [16] recommended "that universities should consider a further range of courses designed to attract into science, engineering and technology, able students who are not already committed to these forms of study but who are otherwise qualified to benefit from ab initio courses in these subjects at university level". The science-generalist courses in British tertiary institutions are, at least in part, a response to this recommendation. In the Division of Interdisciplinary and General Studies at the University of California, the program "The Creation and Transmission of the Sciences", although at present a two-year undergraduate program which provides a general introduction to the sciences, is intended to become part of a science degree program. It is taught by a team of instructors including a physicist, a medical historian, a journalist, a biochemist and a mathematician. The University of Maryland has a number of "integrated" courses, particularly in the chemistry department, where efforts have been made to reduce or eliminate subdivisions within the subject of chemistry.

An interesting development on the British University scene has been the establishment of the Open University which, in contrast to other British Universities, admits any persons over the age of 21 as students, irrespective of their school qualifications. The Open University offers a four year science program, Science Foundations, the first year of which is 'integrated'. It includes aspects of physics, chemistry, biology and earth science in a context of science in society.

The aims of the first year course and the way in which it is implemented are outlined in the following statement which is given to students.

> "One of our aims in designing this Course was that it should be an integrated multi-disciplinary course, with contributions from physics, chemistry, biology and Earth science, but linked together in such a way as to demonstrate the unity of science as well as its diversity. We try to show what is common to all the disciplines as well as what is special to each. This has seldom been done before at first-year undergraduate level.
>
> Another aim was to teach science in its social context–to bring out clearly the relationship between science and society. Again, this is breaking new ground. A few Universities in Britain offer special courses about Science and Society, but none attempt to teach the main science courses themselves in this way.

A third aim was to offer a course that would be both satisfying and worthwhile for those of you not intending to go further in science studies but which would, equally, be a useful foundation for higher level science courses.

And then we had the problem of how to avoid boring those of you who already knew some science, without bewildering the ones who don't know any at all. Unlike the ordinary universities, in which all the students in a first-year class have very much the same background and preparation (a particular set of A levels, for instance), Open University students have widely different backgrounds. As we explain in Section 2.1.1., we thought of a possible way round this problem in terms of what we call 'red pages' and 'black pages'.

Last, but by no means least, there is the problem of laboratory practice. You can't learn science without doing experiments, and so we include experimental work as an integral part of the system.

You will be doing experiments at home, with 'home kits' specially designed for the purpose. These kits will be lent to you for the period of the Course. Each one is worth about £150—considerably more than the whole of your fees. No one has ever tried to organize 'home experiments' on this scale and at this level before.

Then, at the Summer School, you will have the opportunity to do some intensive experimental work in a fully-equipped university laboratory. Here too, the experiments have been specially designed to meet the varied needs of Open University students. Whether you are an experienced laboratory technician, a science teacher, or someone who has never before been inside a laboratory, we hope that the Summer School laboratory sessions will be a challenge, an enrichment and a help to your understanding of what science is all about.

We are going to use television too as a means of augmenting your experience of laboratory work. With the help of the television camera, we shall sometimes be taking you into laboratories that the ordinary first-year student would never see, and we shall on occasions be expecting you to 'take part' in the experiments.

In at least five ways then, this Course is unusual: it is multi-disciplinary and the separate disciplines are integrated; science is taught in the social context; the Course is intended for both the 'science' and the 'non-science' student; it caters for widely different backgrounds; and it has an adequate laboratory content in spite of the dispersion of the students.

We have emphasized the novel features of this Course and later on we discuss the consequent need to improve it in the light of experience. But to be quite fair, to ourselves and to you, we should tell you that never, in all the experience of university teaching that any of us in the Science Faculty have had, have we ever seen anything remotely approaching the amount of careful planning and design, of attention to educational technique and of time spent on producing a single course. For each hour that you will spend on your studies, someone in the Faculty has spent at least sixty hours preparing the material you will study—and this doesn't include the contribution of the BBC producers or of a number of other people in the team. So, even if there will be plenty of scope for improvement, we are confident that you are going to get good value for your money!"

The Open University is an exciting new development in tertiary education. For readers interested in obtaining more details of course production at the Open University there is an excellent series of four articles by Professor Brian N. Lewis, Deputy Director of the Institute of Educational Technology, in the British Journal of Educational Technology, January 1971 to May 1972.

In Australia, the general approach to giving width in science studies is reflected in the statement made by one institution "Generally we regard the integrated and interdisciplinary nature of our courses (programs) as arising from the range of units from which a student may select, rather than from any unusual breadth of coverage in individual units." This attitude appears to be consistent among the majority of tertiary institutions throughout the world.

The assumption underlying this approach to integration is that students will see the relevance of each course (unit) in relation to the others and, hence, integration will be achieved in the minds of the students. It would seem, however, that integration by this method is doomed to failure. At the best, it is a pious hope and at the worst, an excuse for disregarding the complex problem of devising single courses with "breadth of coverage".

Parsegian [6], in discussing the need for elimination of disciplinary boundaries, states 'Such courses as 'Physics for Poets' or 'Humanities Courses for Engineers' can be made up of interesting tidbits and topics resembling a cafeteria selection of sweets and sours that remain sweet or sour even as they are chewed". He goes on to describe an experience in his attempt to use the laws of thermodynamics to give unity across disciplines and his realization that the students, the majority of whom were from science, mathematics, and engineering departments, were not thinking at a conceptual level. He says "In sharing the experience with my colleagues, I was assured that graduate student unfamiliarity with basic concepts is not limited to thermodynamics, but that the weakness goes far beyond the normal escape from memory because basic concepts are rarely established as such in the students' education".

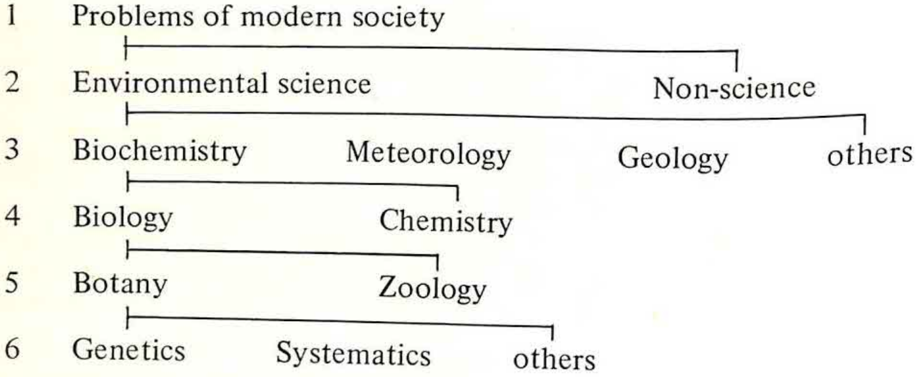
The problems of presenting separate courses in such a way that students see relevance and relationships among them are great and appear at this stage to be virtually insurmountable. The term "integration", used in this context, appears to be a misnomer. Some Australian courses have been designed specifically as integrated courses. Australian programs of an 'integrated' nature include "Chemical Physics", a four-year program at LaTrobe University; "Integrated Science", a first year course at the Riverina College of Advanced Education; courses at the Canberra College of Advanced Education, courses in the Natural Resources School of the University of New England and courses at Macquarie University.

Training of students in several subject areas is not confined to preparation for professional careers and science for non-science students. The third area in which such training is needed is in the preparation of research workers for co-operative interdisciplinary research. One of the anomalies of current tertiary education practice is the increasing narrowness of specialization in doctoral studies at a time when there has been rapid growth in interdisciplinary research fields. The net result is that a lot of time and effort must now be spent in post-doctoral training of interdisciplinary research workers. A well known example of the need for such training is given in Watson's The Double Helix [17].

Terminology

Any attempt to discuss education in terms of structure of courses is be-devilled by inadequately defined terminology. The value of information obtained from the major survey carried out by the Centre for Educational Research and Innovation (CERI) [18] and the relatively minor survey conducted by the author is partly invalidated by this lack of precision. In the former survey, "interdisciplinary" was used to describe "integrated" courses. In both surveys, many respondents expressed their uncertainty regarding meanings of the terms "discipline", "interdisciplinary" and "integrated". The responses show that courses considered to be "interdisciplinary" or "integrated" range from traditional examples, such as combinations of physics, mathematics and chemistry, each taken separately and leading to a B.Sc. degree in chemistry, to new subjects consisting of aspects of others, for example, biochemistry and biology, and finally to studies in which the disciplines are not segregated in any way, for example, environmental science.

An examination of courses regarded as more or less meeting the description "interdisciplinary" or "integrated", reveals a wide variety, ranging from mixtures of traditional subjects to areas in which traditional subjects are not apparent. The need to *segregate* knowledge into narrower channels in order to enable individuals to extend knowledge even further, has been opposed by a demand to *integrate* narrow channels to give wider perspective. Segregation is a relatively easy procedure. There seems to be no limit to man's ingenuity in categorizing and sub-categorizing the universe. Many levels of segregation are possible. An example of segregation at six levels is given below.



Since integration, by definition, is the reverse of segregation, each of levels 1-6 can be regarded as integrations of levels below it on the table. However, discussions on integrated science appear to be concerned with levels 1 and 2 only. Consistent with that apparent usage, the term "integration" is used in this paper in relation to combinations of subjects above level 3 in the table.

What constitutes integration?

The term "integration", per se, used in reference to knowledge, pre-supposes segregation. Integration requires re-combination of previously segregated parts to give unity or to make a whole. One procedure advocated in practice is to mix the parts and hope that the significance of each part will be appreciated by the students. The effectiveness of such a procedure is so questionable that, in the opinion of the author, it is not acceptable as a means of integration. Another procedure, deemed more satisfactory by its proponents, is to show inter-relationships and interactions explicitly by using team teaching methods, by means of which each teacher, although he confines his teaching mainly to his own areas of expertise, is able to cross-refer to other relevant fields where appropriate. Problems of cross-referencing are increased with the number of teachers participating. Hence, teachers with expertise in more than one subject area are better suited to teaching integrated courses. Again, the effectiveness of this procedure is very doubtful and, in the opinion of the author, courses taught in this way do not qualify to be entitled "integrated".

Integration is difficult to achieve to the satisfaction of all concerned, and several ways of attempting to do this are evident. Organization around the historical development of scientific ideas has been tried but found lacking with respect to the criterion of relevance. The approach adopted by Parsegian [6] and others is to build a course around "themes" or "concepts" that offer broad application to a range of subject areas. In his first project he was concerned with topical areas and concepts that were considered important to teach. A similar approach is advocated by contributors to the Nice Seminar on Interdisciplinarity [18].

The most popular method (and apparently the most successful) involves selection of a topic that is an entity in itself, for example, Air Pollution, Cosmic Evolution, Human Ecology, Fungicides and Plant Diseases. The science taught is that relevant to the topic. Where appropriate, knowledge from other subject areas is dealt with in context. Although this type of course appears to be currently regarded as the ultimate in "integration", the term is applied in a very different sense from its usage with reference to the synthesis of a course from a universe of segregated parts. Where synthesis is attempted, one starts from the universe of parts and seeks ways of combining them into coherent units. In the topic method, the starting point is the coherent unit, which is then examined for its constituent subject areas, the relevant parts of which are taught as part of the unit.

Examples of the topic approach are found among secondary science materials, including the Intermediate Science Curriculum Study (ISCS) Grade 9 materials, the Australian Science Education Project (ASEP) units, and the British Science 5/13 materials. Details of these can be found in the International Clearinghouse publication [7]. An examination of these materials and a comparison of them with earlier "integrated" courses shows the topic approach to be very successful in eliminating disciplinary boundaries.

If a parallel can be drawn with the experiences in curriculum development at pre-tertiary level it seems that the "unified topic" approach will prove to be the more fruitful, at least for courses designed for social relevance. Clark [13] has expressed the opinion that "any process that takes material that has already been divided up on the basis of artificial man-made disciplines and then tries to fuse it together again is bound to be less efficient and less successful than one which . . . emphasizes the unity of Nature".

Moves towards integration of the sciences

Whatever way "integrated" science courses are designed, it is clear that the idea of integration is receiving strong support.

The author's limited survey of course trends in British universities indicated that there is a definite trend towards providing integrated science courses at undergraduate level.

That this is a general trend is evident from the Introduction to the Opinions and Facts section of the CERI publication [18] where it is stated that "in many universities throughout the world there is currently emerging a desire for the integration of disciplines or at least for establishing interdisciplinary activities". The observation is also made that "Interdisciplinary teaching and research are the key innovation points in Universities".

While there seems to be strong support for moves towards integration and the breakdown of subject boundaries, there is also strong agreement that it is very difficult to establish such courses at the present time. An example of the problems facing the innovator is the opposition to the recent establishment of the School in Human Sciences at Oxford. Details of the debate are published in the Oxford University Gazette, November, 1969. Arguments against the establishment of the school include:

(1) the programs aim at producing experts but cannot succeed because of their non-specialized nature

(2) the programs contain too much for the students to learn and will be unteachable, because of their breadth

(3) university standards will be lowered
(4) students will lack adequate training in critical thinking
(5) the creation of a new school will over-strain university finances
(6) it will be difficult to find suitable teachers and tutors.

Points 1, 2, 3 and 6 make unjustified assumptions about the duration and organization of integrated courses in the total program. The fact that such programs can produce experts and are teachable is evident from their success at many other tertiary institutions, including Indiana University, University of British Columbia, University of Maryland, University of Stirling and University of Keele. Point 4 implies that earlier courses provided training in critical thinking. If they did, there is no reason why similar techniques could not be used in the new courses. In fact, a widening of the scope of a course can lead to better concept development and more critical appraisal of evidence submitted. Point 5 is not an argument against integrated courses.

This debate is of particular interest in that it summarizes the opposition expressed in many places against courses designed to cover a range of subject areas, whether "integrated" or "unified". Opposition stems from a number of sources, the biggest problem being that the combination of subject areas cuts across the traditional organization of tertiary institutions into "disciplines". Attempts to bridge the "disciplines" interfere with the entire social structure of the university. This not only antagonizes those staff members who feel insecure outside their own specialities but creates operational difficulties in terms of scheduling, budgeting and general administration.

The within-institution discipline-oriented organization is reflected in, for example, the fields in which careers are available and in the types of research journals published. Such outside influences create further problems for both teachers and students of the new courses.

One way of solving the major problem of breaking down barriers between disciplines is the establishment of multidisciplinary structures in the institutions. This explains the more frequent appearance of integrated courses in new institutions. It is evident, however, that a changed structure does not ensure the development of integrated courses.

The biggest barrier to progress appears to be ignorance of how to establish courses that involve teaching in several subject areas simultaneously. The present teachers and administrators of tertiary institutions are specialists, usually in one subject area only. Not only do they find difficulty in seeing science in overview but they often show lack of respect and even contempt for workers in other subject areas. Worst of all, they are unable to define the goals of their teaching programs clearly.

In the last few years much progress has been made in determining how tertiary institutions can define their goals and the goals of their teaching programs. An outstanding example of how this can be done is the work of the Institute of Educational Technology at the Open University. This work is described in detail in the series of articles referred to earlier in this chapter. Many other universities have set up special divisions whose task it is to research the teaching process and assist in the definition of purposes and goals.

Most tertiary institutions have not attempted to clarify the ends for which their structure, at the institutional level, and their courses, at the subject level, are designed. Until this is done there can be little meaningful dialogue on program and course objectives and there will be great difficulty in rationalizing the purposes of tertiary education activities. The establishment of curriculum development centres would facilitate the introduction of integrated courses in tertiary institutions. The newly established Center for Unified Science Education at Ohio State University, under the directorship of Dr Victor Showalter, will act as a resource centre for information on unified science. Many others of its kind are needed.

The case for integration of science subjects in tertiary institutions is argued strongly by advocates of education in its wider sense. People need an understanding of science, its scope and its limitations, if they are to operate as intelligent citizens in modern society. The problems of modern society require attack on a broad, multidisciplinary front, extending well beyond the subject boundaries of science. Most science related careers require a wide background in science and specialist training has been found to be inadequate in that it tends to yield narrowly-competent, widely-ignorant products.

Concurrently with integration, provision must be made for education of scientist-specialists and scholars who wish to pursue research in specialist fields. The present system of tertiary education is producing more scientist-specialists than there are appropriate career opportunities. Where integrated courses have been set up in traditionally organized institutions, they tend to be tolerated as a whim or a luxury. They may even be encouraged but there is strong evidence that the system does not intend to give in or allow this recent innovation to dominate.

The most successful courses in terms of the elimination of disciplinary restrictions, tend to be "unified" rather than "integrated". They tend to be developed in newly formed institutions, staffed by teachers and research workers convinced of the value of presenting science as part of human endeavour and, as far as practicable, unsegregated. These courses are most satisfying to students when science is presented in context of present-day society and every-day life. Many successful courses adopt a problem-focussed approach.

The universities are only just beginning to feel the impact of the demands of a greatly expanded student population, for an education that is relevant to the modern way of life and that will equip them to attack problems attributable directly or indirectly to the rapid growth of science and technology. Attempts are being made to meet the challenge but on an ad hoc basis with little evidence of co-operation between institutions. If traditional tertiary science education is as out of step with modern society, as this review suggests, a concerted effort by people and organizations of recognized authority is urgently needed. Such an effort could solve many of the problems of integration but, if the effort is to be successful, the field of view must be widened well beyond the scope of science. Science is only part of total human endeavour.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the information received from many individuals and organizations in response to his request for details on existing and proposed integrated tertiary science courses. Many individuals went to a lot of trouble to provide information despite inconvenience that must have resulted from the arrival of the request at the end of the academic year. Their assistance is doubly appreciated.

The author wishes to apologize to all who sent information but who have not been mentioned in the review. A special apology is owed to those institutions at which significant advances in integrated science teaching are being made but, due to inadequacies in the author's survey, are still unknown to him. Finally, he regrets that his remarks are restricted almost entirely to developments in the United Kingdom, Australia and the USA. His information on developments in other countries, is limited almost entirely to the following comment made by Douglas J. Aitken, Executive Secretary, International Association of Universities, who referred to the CERI publication [18].

> "I regret that we cannot immediately refer you to a corresponding set of information for the socialist countries. However, recent reforms in Poland and particularly in the German Democratic Republic—where the faculty structure has been replaced by a series of subject sections—have undoubtedly provided new opportunities for the development of integrated courses of the kind you mention."

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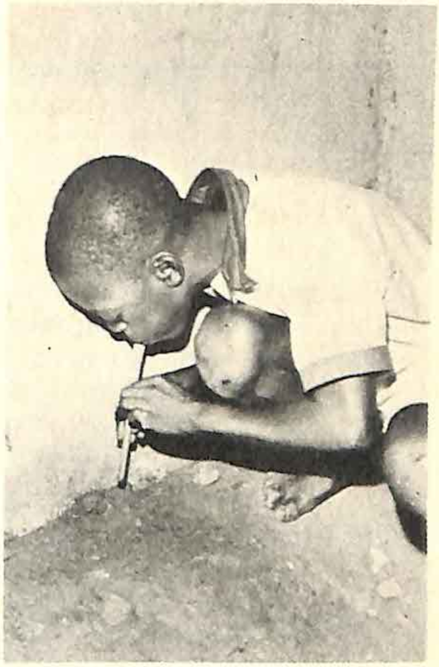

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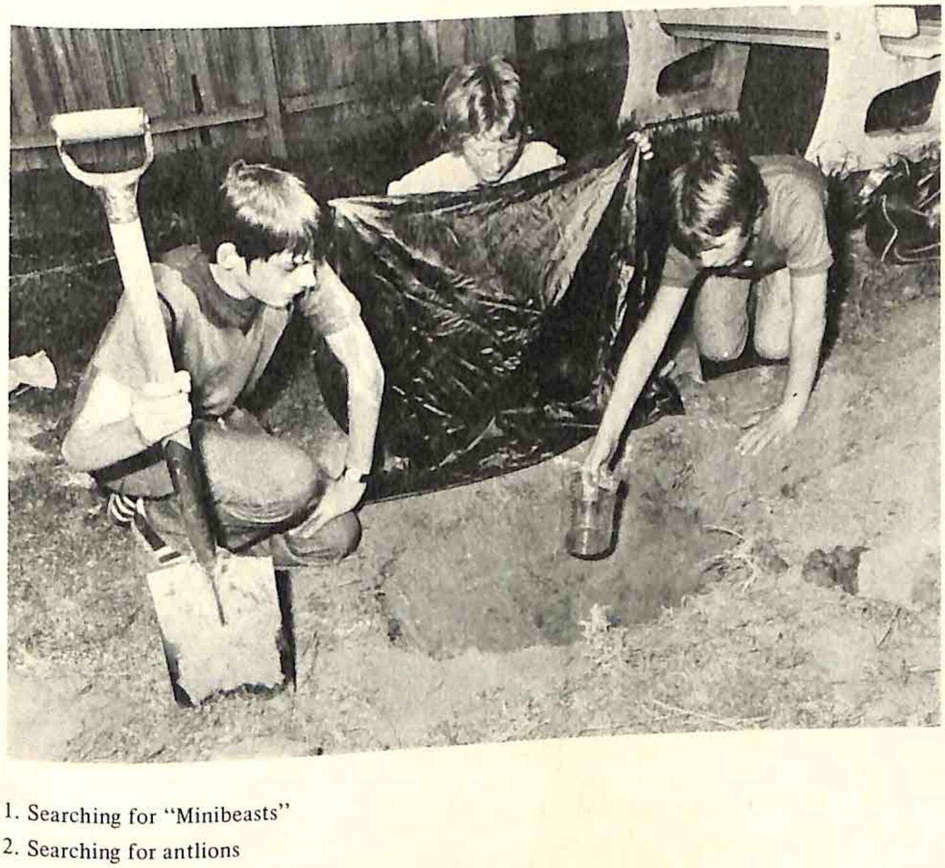

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1. Searching for "Minibeasts"
2. Searching for antlions
3. Preparing a survival water hole

Chapter 6

'THE USE OF LOW-COST MATERIAL, EVERYDAY ITEMS AND LOCALLY-CONSTRUCTED APPARATUS FOR TEACHING INTEGRATED SCIENCE'.

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Summary

The many schemes now in operation to teach integrated science show a common strong trend towards using locally-obtainable material. Pedagogic advantages of its use are the probable suitability to the pupil's background and relevance to his own and his country's needs. The major advantage of low cost makes it possible to provide for pupils' personal experience in science. Perhaps the most serious difficulty however is the demand it makes on the teacher in collecting, building, modifying etc.—and teachers alone can rarely do enough.

Various projects are in operation to process local materials, either by complete manufacture or cottage industry. Other projects aim to help the teacher to overcome the limitations of time, competence or confidence and to improvise items for herself. There are also sources of less expensive standard apparatus for schemes which use some conventional items or need them as models to be copied.

Relatively few schools in the world have yet attempted one of the varied possibilities of giving children the practical experiences they need in integrated science. There are however now enough exemplars of projects using low-cost apparatus to encourage individual teachers or whole school systems to plan to include ample practical work in their teaching.

Simple apparatus and pupils' experiences

Some forty or fifty years ago, wandering craftsmen in the countryside of China used to repair the housewives' broken crockery. No doubt they had done this for hundreds of years before, and no doubt they still do it. With a hammer, a pair of pliers, some brass wire and a bow-and-string drill tipped with a quartz or steel particle, they would drill beside the broken edges of the pot, form brass staples and tap them in. The vessel might ooze a little at the crack but the repair was effective for its purpose. It cost little but the labour.

There are however reasons other than mere necessity and lack of sophisticated supplies that lead people to use for their tasks materials that are to hand. At present in Big Sur, California, U.S.A., communes of people who have deliberately cut themselves off from normal city life build for themselves geodesic domes to live in, formed elegantly from panels cut from the roofs of scrap automobiles. In West Africa schools are turning to a curriculum for primary and early secondary schooling based on material from the children's surroundings: on kitchen physics, pond biology and food chemistry.

The motive behind these activities is an ideology of relevance. The sophisticated materials are available but are felt to be inappropriate. In the communes it may be a kind of liberty from the unrealities of city life that is being sought. In science education it is certain that teachers believe that more genuinely scientific attitudes can be introduced through real-life examples and problems. These may be simple on the surface but are often very complex on deeper inspection, and by no means limited to a nominally unitary science subject. The study of real-life, low-cost objects and materials leads naturally to an integration of the sciences.

For a period of many years however, the teachers of science withdrew themselves from the practices of the world in which the children lived. Governed by a feeling for the abstract expression of simple principles, by a desire for the refined apparatus which seemed appropriate to the formality of the laws of science and by a need to examine the pupils' learning by methods that allowed easily-performed grading, the teachers moved towards highly-specialised, uniform laboratories and towards an isolation of areas of study which became the separate subjects: physics, chemistry, biology, geology, etc. Apparatus became so conventional that teachers came to believe that if they had no 'Boyle's Law Apparatus' they could teach Boyle's law only from the textbook. They became ashamed to reach for a common bicycle pump.

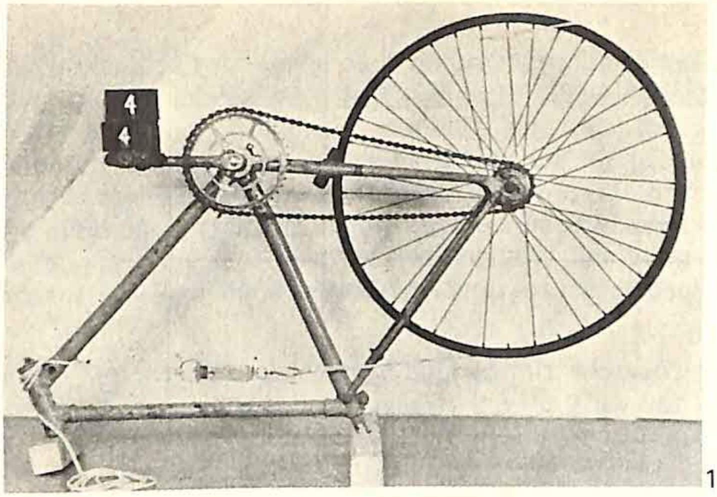
During the last ten or twenty years, education has for many reasons begun to turn away from the restrictions which have grown in the last hundred. In some schools, science is beginning to be taught with common everyday objects and the curricula are being shifted towards the needs of the children and their needs as adults. They are being encouraged to handle apparatus for themselves and to realise knowledge through their own hands. What were thought of as subject boundaries are being crossed, not only between the sciences but into literature and history. Some individual teachers teach many subjects and teams of teachers (each perhaps a different specialist) may be found dealing with studies of old age, racism or safety in the home. Science thus becomes not a subject but an integral part of whole areas of life. It is in such studies that low-cost apparatus and every-day objects for use in teaching science really come into their own.

As a result some blackboards have disappeared, science benches have become movable (and any one may become the teacher's demonstration table). Further, science begins no longer to find a laboratory a necessity; experiments are being devised to be done at desks. Cups are replacing special beakers and bottles begin to take the place of flasks.

The rationale for using everyday objects in integrated science teaching

Obviously a major virtue in using simple apparatus is that it is relatively easy to obtain in adequate quantity for the classroom. With it there is a real opportunity for pupils to experience phenomena for themselves, with all the advantages which such real activity brings to the children. There are however other equally important advantages.

Children enjoy studying science, they enjoy detecting relationships, patterns and constancies and their pleasure can conveniently be aroused through "common-life" activities. Educators urge that children should begin their work on a topic with "concrete" experience, with ordinary things which they can handle and common things with which they can become thoroughly familiar and in the process discover some of the characteristics and the relations of one object or class to another. The teacher will naturally guide this but will avoid direct teaching of abstractions, letting the pupils come slowly upon them by an unobtrusive, unforced process of development. A teacher who begins with an abstract finds himself thwarted if he tries to illustrate it, because a concept is formed as the result of several experiences which have been refined by the mind. The first experiences need to be 'concrete' not verbal or mathematical. The illustration should come first.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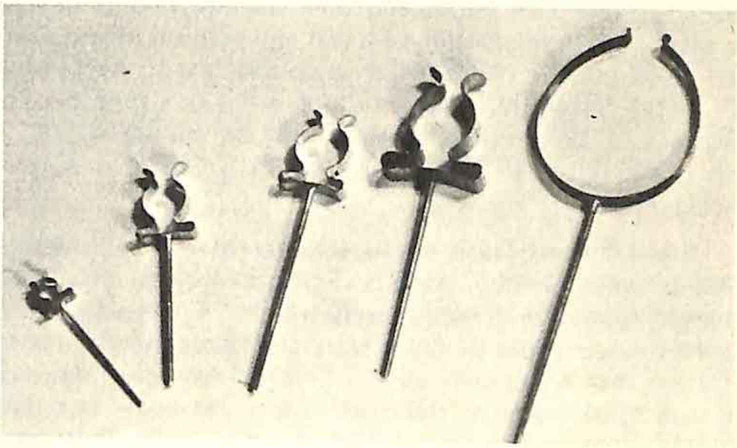
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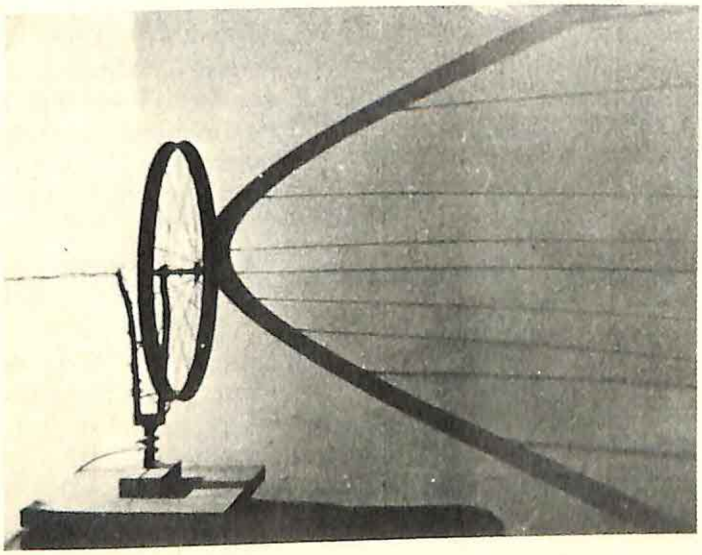
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1. The use of "real-life" apparatus when studying the transfer of force: in this case from pedal to rein.
2. Tool clips and trouser clips as tuning forks.
3. A bicycle wheel casts a parabolic shadow.

The old method, developed during the last hundred years, drew an arrow on the blackboard, named it a 'ray of light' and proceeded through weeks of study (with glass blocks and pins perhaps) until as a culmination it arrived at a real telescope. This was satisfactory for many of the pupils then. The school courses were designed for selected academic children of the grammar school or l école normale who could be relied upon to have had in their homes experiences from which the concept of 'a ray of light' had already been formed, though possibly in an inchoate way. Today the situation is no longer the same and teachers feel the need to begin the series of lessons by presenting a pair of common spectacles or a crude telescope, home-made with their lenses, as initial practical experience.

There are other virtues in starting with 'concrete' things. One is of course that the process is suited to the use of every-day objects in the early stages of each science topic, and to 'do-it-yourself' techniques and local resources. To start with a flashlight, a length of cotton thread, or of yarn or a piece of soap is to use something whose character children both partly know already and partly need to know better for their later lives. It is certainly easier to be intelligently curious about these than about the standard equivalents in science teaching, which maybe a 'ray box', a steel wire, a microslide of a cell and sodium oleate solution. The teacher has existing knowledge to build on; the children feel a confidence to start experiments; the items can be obtained in the locality. Naturally, as a result of using this type of simple material, a whole range of different aspects of the work is brought into the pupils' studies and interconnections present themselves to the children in a natural way. In short, an integration is in-built into this way of studying science.

A good illustration of an integrated science course which demonstrates this rationale is the Papua New Guinea Primary Science Project. It illustrates how specialised apparatus can be supplemented by locally-purchased items. Consisting of three teachers' handbooks in English, it uses sixteen types of basic standard apparatus for the children, working in groups of four. The teacher has some two dozen items of standard equipment of a similar, simple type. About a dozen local resource items are added to these but the rest of the needs are brought in by the children themselves. Its philosophy and the content of the work is similar to other schemes described in this article. UNICEF supplied the basic items originally in a storage cabinet and the Education Department provided the local resource items. Collection and preservation of a wide variety of items is urged on the teacher, whose 'laboratory' is expected to be only a normal classroom with the cabinet and what ever else he can assemble to improve it. Later stages involve projects as described later in this article and the use of radio broadcasts. The guides are in the form of teachers' worksheets with the general form of: 1. 'you will need', 2. photograph. 3. 'do this' and 4. extra activities for children who have time to go further and need extending..

The Papua New Guinea Primary Science Project /Lists of material recommended by UNICEF

Equipment List No. 1
UNICEF Children's Apparatus

Item	*Number Supplied*
Burners	10
Forceps	10
Beakers, 250 ml.	10
Clamps	10
Funnel, plastic	10
Rubber tubing, 3 ft. lengths	10
Scissors	10 pairs
Plotting compasses	10

Equipment List No. 1–*contd.*
UNICEF Children's Apparatus–*contd.*

Item	*Number Supplied*
Magnets	10 pairs
Lenses (triple-magnifier type)	10
Bulb sockets with 3 screw type bulbs	10
Plastic tubing, stiff 1 ft. lengths	10
Asbestos mats	10
Copper rods for heat experiments	10
Burning glasses	10
Plastic trays	10

Equipment List No. 2
UNICEF Teacher's Apparatus

Item	*Number Supplied*
Burner	1
Tuning fork	1
Surgical knife handle	1
Blades for surgical knife	2 pkts.
Beaker, 250 ml.	2
Test tube brush	1
Plastic funnel	1
Gauze wire square (for heating experiments)	1
Filter paper	3 boxes
Test tubes	12
Thermometer, laboratory type	1
Rubber tubing	9 ft.
Potassium permanganate	1 bottle
Spring balance	1
Bulb socket with 3 screw type bulbs	1
Pocket compass	1
Litmus paper, red	1 pkt.
Litmus paper, blue	1 pkt.
Iron filings in shaker type jar, 1 lb.	1 jar
Connecting wire, plastic covered	1 reel
Connecting wire, uncovered	1 reel
Corks to fit test tubes	6
Corks to fit bottles	6

Equipment List No. 3
Items to be supplied by the Education Department through your District Inspector

Item	*Number Supplied*
Torch Batteries	24
Mirrors, 6" x 4"	20
Rubber bands, 2" x 1/8"	1 box
Rubber bands, 3" x 1/4"	1 box

Equipment List No. 3—*contd.*
Items to be supplied by the Education Department through your District Inspector—*contd.*

Item	*Number Supplied*
Paper clips 'GLIDON' type	1 box
Bicycle pump	1
Padlock, for locking science cabinet	1
Gut fishing line	50 ft.
Cotton wool, 1 lb. roll	1
Lead sinker for use as pendulum weight	1
Single edged 'GEM' type razor blades	20
Candles	12
Plastic bags	100
Balloons	48
Torch bulbs, 3.5 volt	20
Pulleys	10

It is worth noticing that the Papua New Guinea Project and similar schemes avoid the discouraging remoteness which enters lessons with specialised 'standard' apparatus and the old-time approach to science teaching. This risk of remoteness particularly applies to the physical and chemical aspects of teaching integrated science. It requires an intellectual and imaginative effort to see that the principles which apply to the special Boyle's Law Apparatus, with its shaped glass bulbs, complex stand and rising level of mercury are the same principles which apply to a bicycle pump.

If a child is schooled into an expectation of clear-cut standard equipment, he may tend to take the extreme position of supposing that this kind of thing alone is science and that real life has nothing to do with it. That this is true may be verified by questioning almost any adult who did a science course in school as a child. The hopes of the teaching system are that the pupil is being given knowledge for use, but the method all too often disposes him not to use it because he feels that it has only the remote specialised applications that he has experienced. Pupils who have seen a gas preparation experiment in chemistry with its peculiarly English 'Beehive Shelf' and specially-shaped 'Delivery Tube' will hardly believe that a common bit of soft plastic tubing will do the same job. They come to believe, in these and similar cases, that only the special device is possible and they associate that bit of science almost wholly with that particular apparatus.

It is perhaps a matter for argument whether a child learns better from a 'real-life' object (incorporating aspects irrelevant to the main concept to be understood) or from a specially-designed teaching apparatus without such distractions. It is however possible that a concept presented through a 'real-life' item aids the child to apply that concept more readily to his life outside the school.

Further Examples of Integrated Science Courses, Projects and Related Work

One of the interesting developments in many parts of the world has been the use of 'projects'. The idea in these is that children should investigate for themselves some situation (rarely as small as a single object), generating their own enquiries and following them as far as they can. This, in fact, is a strong element in the African Primarv Science Program. Their book 'Making things look bigger' leads children, through the pleasure of satisfying their curiosity, to find answers to questions that arise naturally when inspecting through home-made microscopes and standard, cheap magnifying glasses, the commonest of materials: the physical structure of a fly's wing, the crystallinity of sugar and soil nematodes. At the primary stage little of a written nature is required but the experiences will be basic to subsequent building of theory. Towards the other end of the age and academic scale, come the projects by pupils and teachers described in the English publication 'SATIS'. Some of these projects are single-discipline experiences but others involve all the sciences and are often low-cost, providing examples which can be followed anywhere in the world. The point about apparatus for a project is that it usually needs to be of an improvised kind. Often there can scarcely be suitable standard apparatus.

The principal aim is always to make the teaching of integrated science relevant to the children's needs. There are other aims and other strategies (worksheets to help the pupil go at his own pace, the use of new media to increase the lessons' attractiveness) leading in the same direction. But relevance is likely to give the children more motive to learn and a greater usefulness to the country once they have done so.

In the U.S.A. there are many such courses at various levels. An important one is "Elementary Science Study" published by McGraw Hill for the Education Development Centre, Massachusetts. Dozens of books, kits and films lead children through studies closely connected with their environment, using natural objects and local resources. It is one of the virtues of almost all the books described in this article that they show the children actually in the process of using the apparatus as an encouragement to them and their teachers to use simple items for real science. E.S.S. uses many such photographs and describes its scheme in a way that can stand as a world-wide definition of most of the courses of its type:

> 'Some units are neat, some are messy. They use special equipment or what you happen to have around, supplies you can buy anywhere or the children bring in. They involve taste, sight, hearing, touch, smell and movement. Most units go on in the classroom, some in the corridor, in the gymnasium, in the school yard, on the street, in the countryside . . .'

There is a very wide range of E.S.S. Units from which a teacher can choose starting points for children's investigations. They are listed below together with a list from the African Primary Science Program. A comparison of the two shows clearly that a Unit approach to integrated science is applicable in widely different environments. An imaginative teacher anywhere in the world can find around him areas of study needing very little specialised equipment. What he must do is to start the child going on something that is engrossing to him.

Elementary Science Study Units (U.S.A.)

Light and Shadows
Growing seeds
Match and Measure
Mobiles
Life of Beans and Peas
Primary Balancing
Butterflies
Pattern Blocks
Geo Blocks
Eggs and Tadpoles
Tangrams
Musical Instrument Recipe Book
Attribute Games and Problems
Rocks and Charts
Starting from Seeds
Where is the Moon?
Colored Solutions
Mosquitoes
Whistles and Strings
Bones
Small Things
Tracks
Crayfish
Budding Twigs
Animal Activity
Earthworms

Elementary Science Study Units (U.S.A.)—*contd.*

Animals in the Classroom
Spinning Tables
Brine Shrimp
Changes
Printing
Mirror Cards
Pond Water
Daytime Astronomy
Sand
Structures
Sink or Float
Clay Boats
Drops, Streams, and Containers
Mystery Powders
Ice Cubes
Peas and Particles
Batteries and Bulbs
Optics
Pendulums
Micro-Gardening
Senior Balancing
Behavior of Mealworms
Stream Tables
Water Flow
Mapping
Heating and Cooling
Balloons and Gases
Gases and "Airs"
Batteries and Bulbs II
Kitchen Physics

African Primary Science Program Units

Lower Primary

Plants in the Classroom
Exploring the local community
Dry Sand
Wet Sand
Water
Cooking
Construction
Woodwork
Wheels
Arts and Crafts
Playground Equipment

Middle and Upper Primary

Exploring Nature
Seeds
Small Animals
The Water Book
Ask the Ant Lion
Mosquitoes
Ourselves
Chicks in the Classroom
Tilapia
Buds and Twigs
Making Paints
Colours, Water and Paper
Sinking and Floating
Torch Batteries and Bulbs
Changing Solids
Making a Magnifier
Friction
Estimating Numbers
Making things look bigger
Liquids
A Scientific look at Soil
Inks and Papers
Construction with Grass
Powders
Chima makes a Clock
Measuring Time: Part I
Bricks and Pots
Tools for the Classroom
Making a Microscope
Balancing and Weighing
Sound: A look at Musical Instruments
The Moon Watchers
Stars over Africa
Strangers in the Sky
Using the Sky
How the Sky looks
Common substances around the Home
Measuring Time: Part II
Pendulums
A Book about Pendulums

An English publication series 'Science 5/13' uses similar techniques to achieve the same aim. Its titles include: 'Working with wood', 'Time', 'Toys', 'Structures and forces', etc., which provide opportunities to look at whole areas of experience. The series works with materials that are easy to obtain in addition to standard items so that plenty can be provided for the children's experiences. Two more important points arise however. Firstly, common items such as wood, chickens, structures and cooking involve all the sciences in an essentially natural way. Secondly, all the items are by their nature part of the children's own lives. Courses such as this are true integrated science because 'separate subjects' just do not arise. On the other hand, 'Construction and Forces' of 'Science 5/13' allows children to perceive for themselves the unifying concepts illustrated by skeletons of birds' wings and model aircraft wings, the structures animals build and plant structure, rock strata and crystals etc.

The Nuffield Junior Science books are another prolific source of ideas on the use of locally-obtainable material for teaching integrated science. The books are the result of a large-scale experiment in education in England. The books are for teachers and consist of: guides, source-books of information and ideas on apparatus, animals and plants and background books on keeping mammals in the classroom, etc. Despite the fact that the material is such as is locally-available in England, the ideas for its collection, maintenance and presentation to children are of world-wide use.

A small scheme being initiated by R.M. Garrett for school trials in Colombia attempts to achieve relevance for the children of a developing country with Latin American countries particularly in mind. Its aims are to be low-cost, flexible and gradually built up on the realisation of emerging local needs. Much local resource material is used in conjunction with 'modules' of worksheets and basic apparatus for use in 'topics' or groups of allied activities for some three hours per week. It is 'aimed at giving the child an understanding of basic underlying scientific principles or, more confined in approach, giving the child knowledge that will help him see and overcome immediate problems in his life'. CEDO, England, are supporting this project.

The high cost of standard apparatus for integrated science

There is a growing feeling both within developing countries themselves and in the international agencies which give advice and aid, that obtaining science teaching materials from the richer countries is disadvantageous in the long run although very valuable at the setting-up of new courses or new types of school. The cost of the item can be high, even when it is made of parts whose intrinsic cost is low, owing to such matters as the high cost of labour in the richer countries. Schools with a low laboratory budget could benefit substantially from local construction of items whose assembly is only a semi-skilled matter.

Modern science courses lay great stress on student manipulation and often try to insist on each pair of pupils having a version of the apparatus being used. Insufficient supply of apparatus for pupils goes against the whole intent of the new curricula. Any savings by local purchase could go towards providing additional, multiple items which help in the implementation of some schemes.

There are other important reasons for a country wishing to avoid importing foreign teaching items. The cost of shipment is a large part of the total expense and the time between ordering and receiving equipment from foreign manufacturers may approach a year. Spare parts and replacement items are not readily obtainable (which is often a major trouble to science teachers). Other concerns are the national finance of the country itself and the general cultivation of a feeling of national independence.

However, while these are problems which face school systems ordering from foreign manufacturers through normal commercial channels, some of the difficulties drop away if use is made of one of the U.N. agencies.

UNICEF as a lower-cost source of integrated science teaching apparatus

The U.N. Children's Fund (UNICEF) stocks and supplies a wide range of material within the fields of education, agriculture, health and child care. Items may be requested by projects. They are catalogued in some 17 lists, ranging through: vocational training materials and tools, audio visual equipment, school subject items, agricultural implements etc.

A revision of the science teaching sections of one of these Guide Lists (EVE Science Rev. OSU-6000) has just been undertaken in conjunction with UNESCO. This describes a wide range of apparatus and also includes some 20 publications of use to teachers, lists of plans for local construction of items for curricular development and a list of constructional material for apparatus to be devised locally.

A supplement (Illustrations of Science Teaching Apparatus and Equipment available from UNICEF OSU-6000 Supplement 1) provides line diagrams of all items except tools.

The items have been carefully selected to cover most science teaching requirements other than the highly sophisticated, the very expensive and those shown by previous experience to be too breakable in transit.

A Teacher's Guide to the EVE items is currently being prepared for issue in 1973, covering use of the items, maintenance, repair and the supplementing of them from local resources.

Large-scale manufacture of integrated science teaching apparatus

The manufacture of any wide range of science teaching items by a local national firm clearly needs to be carefully approached if it is to be economically sound even in quite large countries. The capital for manufacturing equipment, the capital tied up on the shelves, management expertise, technical expertise on the shop floor, are the very things scarce in the country as a rule. Moreover, territories with a small but highly important demand are often involved. A production unit, as one unit, covering even one tenth of the range needed is usually quite out of the question. Instances may be quoted of enthusiastic firms, for instance in Trinidad, who have tried for a few years but then had to accept that it is not viable and become merely agencies.

Some larger countries however, after careful selection of the material to be produced, are hopeful of success in manufacture. In Sri Lanka for instance, the Ceylon Curriculum Development Centre has established a Science Equipment Production and Assembly Unit for which UNICEF has provided some finance. It is set up to produce simple apparatus hitherto imported at considerable expense from England and now assembles certain instruments. Interestingly, mobile servicing units are now being provided by this organisation. In a very large project involving wide-ranging curricular development throughout all India aided by various international agencies, Primary and Secondary level science apparatus is being manufactured. The overall requirement is for kits for 400,000 Primary and 80,000 Middle schools involving something over twenty million U.S. dollars. Because of the large cost, indigenous manufacture is envisaged and UNICEF has commissioned a Government of India undertaking, the National Small Industries Corporation to survey potential manufacturers, production capacity, quality standards, prices, inspection and distribution. India's National Council for Educational Research and Training has laid down standards, produced blue-prints for the kit items and has initiated the manufacture of some few thousand kits already. The programme got under way in the second half of the 1960's and is in a pilot phase at present.

The actual apparatus consists of a majority of standard items with some modifications to suit local manufacture and use. New syllabuses, texts and teachers' guides are also being produced.

Science teaching equipment is also being produced at the Science Equipment Workshop of the Rangoon Arts and Science University, Burma. This has so far involved mainly sets of physics and chemistry equipment for the 450 State High Schools teaching science. Certain technical High Schools have also started production.

Construction by small local industries and craftsmen

In many countries there is often a surprising number and variety of small industries. They usually have a very limited line of products or only one product or only one manufacturing technique. However, they are often flexible to a certain extent, being almost one-family businesses with a necessarily keen eye on profit, low overheads and an ability to make new lines using the same know-how and the same tools as the market shifts. Such small businesses are the carpenters, car body mechanics, makers of trinkets for tourists, tinsmiths, the radio repairers, clock repairers, shoe makers and so on and they offer real possibilities for producing apparatus which is not only scientific but also integrated with the community.

Apparatus for local construction has been designed by the Programa Conjunto Gobierno–UNESCO–UNICEF under the Ministry of Public Education, San Jose, Costa Rica. Detailed drawings have been produced and some prototypes made, using wood, tinplate and metal strip. It is hoped that local workshops will be able to undertake the work but there is currently some doubt about the economic viability of the enterprise and the import of low-cost Japanese plastic science kits is being considered.

The Institute for the Promotion of Teaching Science and Technology is a UNDP project in Bangkok, Thailand currently designing and making science teaching equipment in its workshop for use during the project and as prototypes for subsequent local manufacture. This covers the three sciences at upper secondary level and a more integrated form of the sciences at lower levels.

This policy of local workshop construction (and of its possible beginning in a small way) was underlined in the conference sponsored by the South Pacific Commission, UNESCO and the University of the South Pacific (July 1971).

> 'Compared with Asian countries, the South Pacific territories are small in land area and in population. The local production of (science) equipment may therefore have to defer for some time to the manufacture of goods of higher priority to the community . . . Therefore reliance on imported items of science equipment will have to continue, particularly where items of equipment must reach a sufficiently high standard to reproduce reasonably constant results'.

It went on to point out that a progression from complete foreign supply, through elements of 'do-it-yourself' to self-sufficiency when the workshops of the Education Department were producing much wooden and plastic apparatus (and indeed all but the most difficult items) should develop from 'a first stage which might be simple and small, developing in accordance with the indicated needs of schools'.

Some items cannot be produced by cottage industry methods. For instance, if there is not a commercial enterprise which already supplies local laboratories or local hospitals with flasks, glass tubing, and similar glass items, these would need to be bought abroad. However, much glassware has been replaced by polypropylene or even p.v.c. and approximately equivalent items in this material may often be obtainable locally.

Optical glass items have in many schools already been superseded by plastic blocks, prisms and even lenses. Now it will often be found that there is a small firm which has an injection-moulding press which could make these items. In Jamaica, for instance, there are small businesses which make blocks of acrylic resin in which a small butterfly, flower etc., is set and sold to tourists. This technique would be ideal for the production of the transparent optical items. There is in fact a wide range of alternative materials with which to replace older ones and this is being pursued by a number of national projects.

Assembly of parts or of kits in school

It may turn out to be possible to use school pupils for the assembly of items if the teachers think it genuinely useful to their pupils' understanding to be sometimes constructing the items they are learning to comprehend and manipulate. If the children turn out to be capable and if a school feels inclined to pay children after hours to do the work it may be reasonable to suggest that in some cases, a "cottage industry" should merely assemble, minimally prepare and package a 'kit' for pupil assembly. This would be in line with several modern producing and teaching enterprises. In the U.S.A. for instance, Macalaster Ltd. produce kits for student assembly, designed to fit definite curricula (unlike Japanese kits which tend to be for the popular market). In Brazil, FUNBEC has designed much material which is now commercially produced in kit form for pupil assembly.

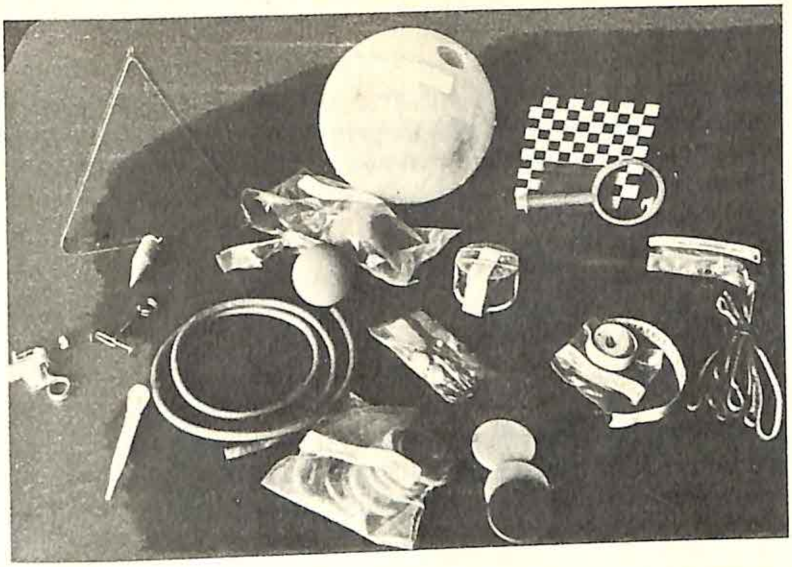
Many of these kits are about the size of pocket books and include equipment and instructions for direct use by pupils. There are some 50 kits covering a wide range of school years, all produced with the objective of creating low-cost experimental equipment for use in school or at home.

The use of existing local hardware for many practical needs in integrated science courses

Many of the raw and manufactured items of physical science teaching material, particularly in the early secondary school years, are in fact locally available, sold on the domestic market for different purposes or already imported by firms for incorporation into their locally-assembled commercial products, or even available from scrap car dealers. Now although none of these materials would be available in large quantities for federal or international markets, they are often quite sufficient for the home countries' schools needs; are in fact in this respect often an almost trivial demand. Add to this those items which can, by a modification of the experimental course in school, teach the same concepts and topics using alternative local apparatus, and it may be seen that a large part of practical integrated science, particularly in early school years may be covered.

A RECSAM adviser is currently implementing this kind of approach at the Institute for the Promotion of Teaching Science and Technology, Bangkok. 'We needed a timer' he said, 'to count a number of short time intervals. Then we thought about a device that is often used in shop window displays (a simple battery-operated oscillating device for advertisements). The small magnet is the only part that will cost very much. It will run for an hour and can be adjusted to operate at different speeds . . . We expect we will be able to have these made cheaply in Bangkok'.

Many electrical items are obtainable, as wholes or parts, from quite small hardware stores, radio shops or garages. Examples are torch bulbs, rectifiers, and power supplies bought as battery chargers. Bicycles are a prolific source of material for experiment. Objects of use in teaching may not only be found but modified, or assembled from parts, or wholly constructed. These processes may be undertaken by pupils or teacher, local craftsmen or a central manufacturing concern. Here the practical limits are set by the local conditions.



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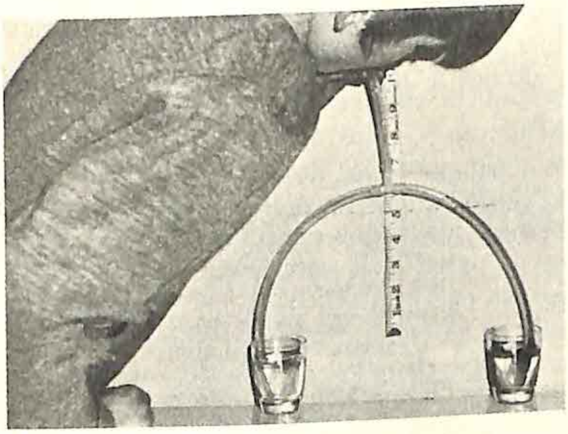

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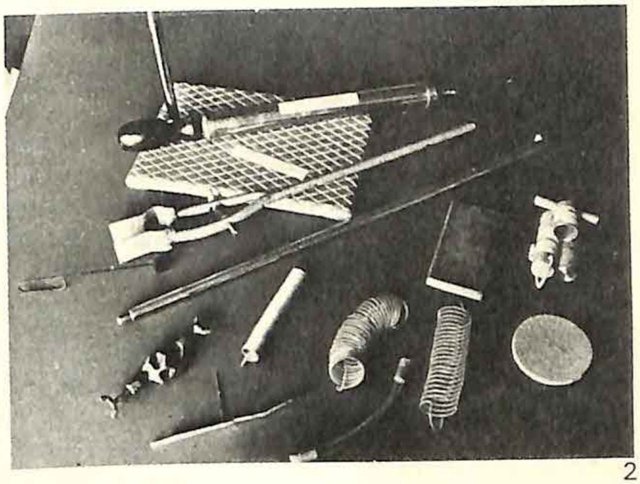

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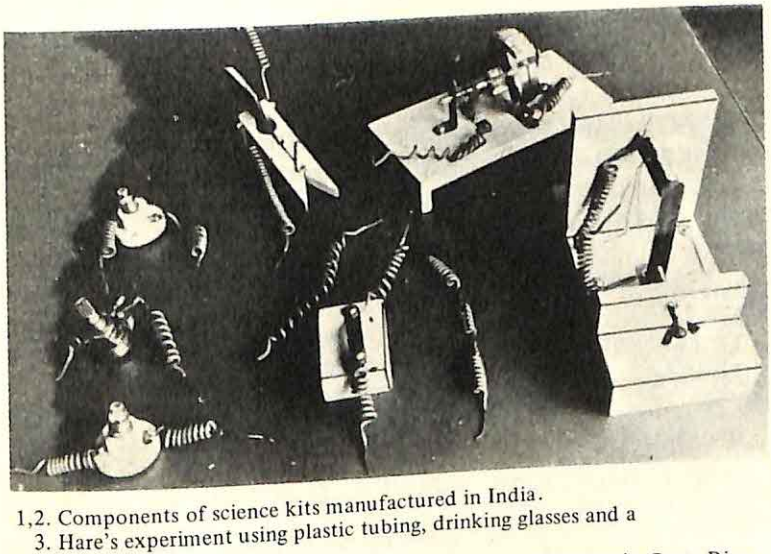


4

1,2. Components of science kits manufactured in India.
3. Hare's experiment using plastic tubing, drinking glasses and a tape measure.
4. Prototypes of simple electrical items for local construction in Costa Rica.

The use of more common everyday items in science teaching

Teachers who begin to consider the matter are often surprised to discover that common objects can be used to illustrate so many scientific ideas and to provide so many experiments from which the needed scientific concepts can be drawn and from which the usual experimental measurements etc. can be taken.

An introduction to the African Primary Science book ‘Constructions’ states this aspect and its relevance very well. ‘ ‘Constructions’ allows children to use many materials: woods, tin, clay, local grasses, stones and other things. They can build structures, furniture or toys. Through handling the materials, children receive an introduction to such ideas as: balance and weight, shape and size, strength and structure of materials. They use: scrap wood, cigarette boxes, matchboxes . . . bamboo . . . string or any other constructional material the children choose when they go out collecting’. For the biological aspects of integrated science, the child’s own body provides innumerable studies thoroughly linked with much physics and chemistry; the various aspects are well covered by the African Primary Program text ‘Ourselves’. Teachers will recognise that the study of local living plants and animals offers similar opportunities.

Physical aspects of integrated science may appear difficult to teach in a practical way unless the teacher has confidence in handling mechanical objects. However, except for the teacher who is firmly set against the idea, the use of everyday domestic things can very much help the process.

For example, the ‘Junior Science Source Book’ (a teachers’ book written to follow up the Nuffield Junior Science scheme but independent of it) aims to suggest how the teacher may start the children on simple scientific enquiries utilising local surroundings and everyday occurrences whether or not she has any scientific qualifications herself. She starts by working with an object that she and the children know to some extent already. Someone in the class will have used it or made it work in real life. It may be a part of a bicycle or an electric torch or a spectacle lens. Many teachers will find it a pleasure that their pupils can give them knowledge as well as receive it and may be further rewarded by the children suggesting new objects which illustrate an idea. Of all the school subjects, science is an easy one for which to find common objects as examples in the early lessons of a topic.

Chemicals and reagents for integrated science work may be thought to be almost impossible to obtain from local sources, from home or market or countryside. However, Dr. A.H. Livermore, Training Adviser, RECSAM, in a SEAMO seminar (Penang, October 1971) remarked ‘Chemicals are all round us. It is not necessary to spend large sums to buy them from laboratory supply houses. Thirty years ago it was not uncommon for chemists to prepare many of their own chemicals from the environment. Perhaps a major activity of curriculum developers in S.E. Asia should be to find more inexpensive materials so that chemistry can be taught as an experimental science’. He preceded this with practical details for making precise pH indicators from common flower petal solutions in alcohol. The UNESCO Science Teaching Project in Asia, based in Bangkok, in its Newsletter for December 1970 suggests many sources of inexpensive chemicals and equipment. Mr. Yaxley in a UNESCO-RECSAM Conference on Integrated Science teaching in Asia (Penang, August 1972) noted ‘There is a well-known and highly-dangerous festival in N.E. Thailand. It involves the firing of rockets made from bamboo and gunpowder mixtures. The people make the charcoal and buy the sulphur and nitre in the market. But where did they get the ingredients two hundred years ago? Fairly reliable sources suggest that bat guano was used’.

A fertile source of rather similar ideas lies in the area of domestic science teaching which integrated science also encompasses.

A delightful example of the use of cheap material on a large scale to teach science is described in 'Playground Equipment' of Kenya Primary Science. Bamboo, car tyres and rope are used to construct towers, slides, swings, roundabouts, large balances and a giant shadow calendar. As the book says 'Without too much trouble and with very little expense, teachers can make playground equipment which will fascinate and excite their pupils. Not only will this equipment make the children's time in the compound more enjoyable but they will be experiencing with their whole bodies some of the important laws of science'.

Aids for the integrated science teacher: pupils as helpers, the provision of model apparatus and general constructional books

Many teachers are already hard-worked but a proportion have, as always, proved willing to collect, modify and build items for their teaching from local sources. Teachers just beginning such a process should realise that the help of pupils is usually called for, either within the lessons or out-of-school. In this way, many demonstration items and a large range of pupil's experimental apparatus of a simple sort can be improvised.

The Science Teachers Association of Nigeria, in association with the University of Lagos Curriculum Centre, at a conference in January 1971, made prototypes of easily-constructed, cheap apparatus for science teaching with a view to subsequent local or school construction. This is part of the current production of draft materials for the 12 states of the Federation of Nigeria intended to cover all the years of secondary science by 1973. In the Faculty of Pedagogy, University of Saigon, South Vietnam, plans are under way for setting up a laboratory to design samples of local and inexpensive laboratory equipment as models for high school teachers. A pilot high school will then evaluate these prior to public distribution. Their concern is that at present few schools are equipped for laboratory work and exercises have been illustrative rather than experimental.

The UNESCO 'Source book for science teaching' describes the construction of some hundreds of pieces of apparatus for teaching science. It covers the three sciences mainly for Primary and early Secondary levels. It is a constructors' book, taking knowledge of the theory for granted but not expecting much initial constructional ability, nor access to anything more than basic science apparatus and tins, bottles, wood, wire, etc., along with simple tools. It is published by UNESCO in English, French and Spanish and by local sources in some thirty-four other languages. It is available from UNICEF, from Guide List EVE. A completely revised edition is currently in preparation.

A series of three books containing a remarkable range of apparatus which may be constructed locally is the "Guidebook to Constructing Inexpensive Science Teaching Equipment" published by the Science Teaching Centre of the University of Maryland, U.S.A., Volumes I, II and III are on Biology, Chemistry and Physics respectively. They consist of clear, three dimensional line diagrams with dimensions and a description of the construction. They represent a world-wide collection of ideas for simple constructions at Primary and Secondary levels of science teaching—probably the most extensive in existence.

For constructional work in schools a small kit of tools is always necessary. The UNESCO Source Book lists these and indicates how to use them. UNICEF supplies a suitable range in Guide List EVE. Both these publications also list materials needed for making simple equipment from local resources. Aiding such work in schools, techniques like those described in the 'Science Masters Books' of the Association for Science Education (England) and in their journal, are proliferating. So are small, cheap tools for such work. Non-science newspapers and journals often carry advertisements for gadgets, aimed at the householder, which can be invaluable in school or college.

Teachers' difficulties

In the monograph 'Providing for a change in Science Education' on early experiences in the African Primary Science Program', R.H. Robins remarks: 'Nor can a program directed towards educational improvement in primary school ignore the fact that even the simplest common materials do cost money and require time to gather, which primary school teachers can ill afford'. Expense is the main factor inhibiting the aquiring of sufficient science teaching apparatus but it has been wisely argued that by thinking of policies that enable schools to get round this difficulty entirely by 'do-it-yourself' methods the status quo is likely to be maintained and the teacher to be condemned for a longer period to a poverty-stricken science room. This criticism has arisen in UNESCO itself about the UNESCO Source Book. Local resources can supply supplements but most teachers lack either the time, the ability or the very tin cans with which to make the *basic* apparatus for themselves. They are being encouraged to use simple materials but they in their turn are beginning to realise that if they are to teach science, they should have a right to at least some basic materials. Probably a teacher's best strategy is both to demonstrate her ability to improvise some of her own apparatus and to demand counterpart supplies from the Ministry of Education. Ministries are often responsive to such enterprise in their teachers.

One set of suggestions for the types and quantities of basic items for teaching science is shown as a selection of 'minimal' items within the EVE catalogue of science teaching items available from UNICEF.

Help to integrated science teachers in training

In the African Primary Science Program Monograph just mentioned R.H. Robins also remarks: 'One country has partially solved the problem by equipping newly-trained graduates from teacher training colleges with simple kits of materials sufficient to teach the units used during their training course. Distribution in this manner is slow but relatively easy to accomplish. It also ensures that materials are provided first to those best able to use them. Other countries thus far have tended to concentrate on those units which require nothing in the way of materials beyond items like containers that children can be asked to bring from home. With heavy stress on biologically-oriented materials, the equipment needs are minimised'. In Bangkok at the teacher training college of Prasarnmitr a workshop and laboratory has been set up specially to help teachers undergoing teaching practice to make their own simple equipment with which to demonstrate and for pupils to use.

Summary of the trends in practical work materials for integrated science teaching

While the schemes for teaching integrated science throughout the world are varied in their details, most of them show a determination to use local, low-cost material for pupils' practical work. The principal reason is to provide teaching that is relevant and suitable to the children and to provide apparatus in sufficient quantities to enable all pupils to gain personal experience in practical work. None of this denies the occasional need for more specialised equipment and the increasing need for it for those pupils who reach the higher stages of secondary education. However, in the primary and early secondary school years, in which all countries have their maximum school population, low-cost apparatus, locally obtained by one means or another, seems the best possible method of providing pupils with the practical experiences necessary to the understanding of their integrated science work.

CEDO, London, has a large display area containing materials, apparatus and references relevant to most of the projects described in this article. The International Clearinghouse, Maryland, contains a world-wide collection of materials and issues a report containing references to all curricular developments in science teaching. UNESCO, Paris, has a wide range of reference material in its "Briefing Room".

This chapter has not included references in conventional style. Instead, the following lists are included as aids to curriculum developers and teachers who wish to follow up ideas and suggestions introduced in the text.

BOOK TITLES

Source book for science teaching. Published by UNESCO 1969.

EVE Science Rev. OSU-6000 & Illustrations of Science Teaching Apparatus available from UNICEF OSU-6000 Supplement 1. Internal document. For access, consult the local UNICEF or UNESCO office.

Guidebook to constructing inexpensive science teaching equipment. Vol. 1 Biology, Vol. 2 Chemistry & Vol. 3 Physics. Published by: Inexpensive Science Teaching Equipment Project, Science Teaching Center, University of Maryland, College Park, USA.

The School Science Review. The journal of the Association for Science Education, England.

Science Master's Book. A series of books incorporating constructional articles from School Science Review. Published by John Murray, 50, Albemarle St., London, England.

Activities for Lower Primary: Playground Equipment. One of a series. Published by Jomo Kenyatta Foundation, PO Box 20533, Nairobi, Kenya.

Junior Science Source Book, by Bainbridge, Stockdale & Wastnedge. Published by Wm. Collins Sons & Co. Ltd., 144, Cathedral St., Glasgow, C4, Scotland.

School Technology. Vols. 1 & 2. A publication of the Schools Council 'Project Technology' containing a selection of articles and project reports. Published by The English Universities Press Ltd., St Paul's House, Warwick Lane, London EC4, England.

Three-phase Primary Science. Three books of the Papua New Guinea Primary Science Project.

A DDRESSES FOR ENQUIRIES.

For the following, see Appendix

- African Primary Science Program
- Centre for Educational Development Overseas (CEDO)
- Elementary Science Study (U.S.A.)
- Funbec (Brazil)
- International Clearinghouse on Science and Mathematics Curricular Developments
- Nuffield Junior Science Project
- Nuffield Secondary Science Project
- Papua New Guinea Primary Science Project
- Science 5/13.

Institute for the Promotion of Teaching Science and Technology, c/o UNESCO, P.O. Box 1425, Bangkok, Thailand.

Kenya Primary Science "Activities for Lower Primary" etc: Jomo Kenyatta Foundation, P.O. Box 20533, Nairobi, Kenya.

SATIS: 27, The Orchard, Locking, Weston-Super-Mare, England.

Association for Science Education, College Lane, Hatfield, Herts, England.

Science Curriculum Centre, Dept. of Education, University of Lagos, Nigeria.

Programa conjunto Gobierno-UNESCO-UNICEF, Ministerio de Educacion Publica, San Jose, Costa Rica.

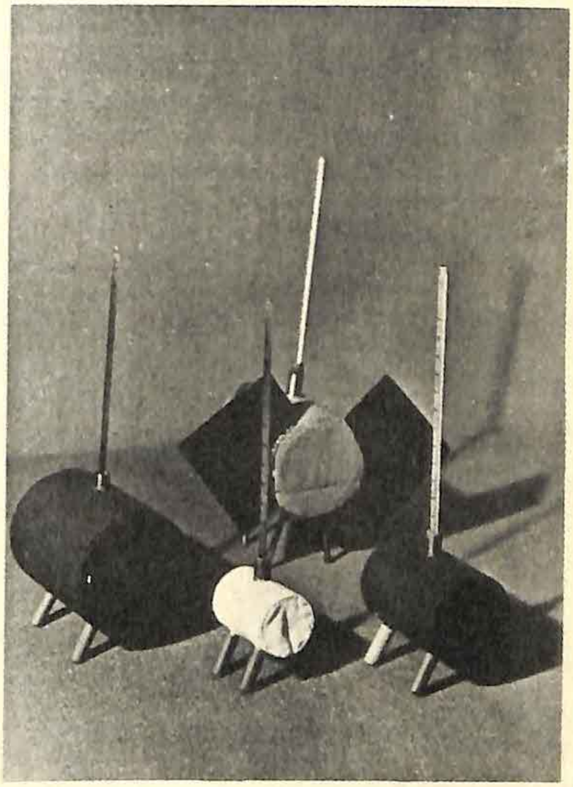
Chief Education Officer, Curriculum Development Centre, Bauddhaloka Mawata, Colombo 7, Ceylon.

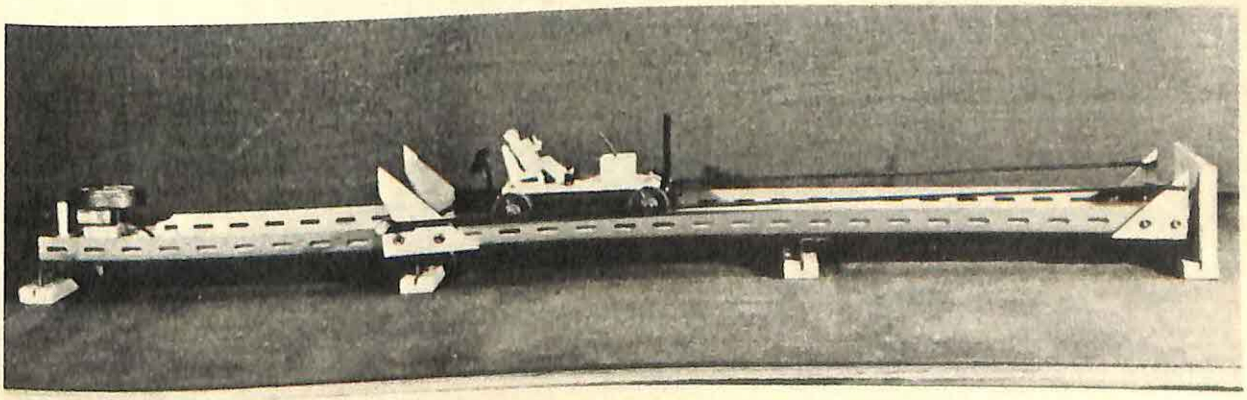
Department of Science Education, The National Council of Educational Research & Training, Sri Airobindo Marg, New Delhi 16, India.

TWO INVESTIGATIONS USING HOME-MADE APPARATUS

The apparatus on the right was devised by Miss M.E.A. Thomas of the University of Southampton in order to study the heat loss in animals of different shapes, sizes, colours and environments.

The model below is based on drawings in the Nuffield Secondary Science Projects Apparatus Guide and can be used to investigate accelerations, braking, inertia, crashes, use of seat belts etc.





Chapter 7

ENVIRONMENTAL EDUCATION AS AN INTEGRATING CONCEPT IN SCIENCE TEACHING

Jan Cerovsky
International Union for Conservation of Nature and Natural Resources

Summary

Environmental education serves as an ideal integrating concept for science teaching and for education generally. Three major stages can be distinguished (1) Teaching *from* the environment (2) Teaching *about* the environment (3) Teaching *for* the environment and the emphasis in primary, middle and secondary school can correspond approximately to these stages. A curriculum based on the environment is integrated from the start and has advantages over coordinated or combined courses in which disciplines are brought together. The use of field studies in integrated science is considered and the place of "conservation" in education.

Introduction

Education is a developing process in which changes in approaches, methods, curricula and teaching aids are always taking place. The constantly increasing knowledge and understanding of science and technology and the new patterns of human life which they entail make change essential in the education of children, students and, indeed, adults. Today's educational innovations are expressions of efforts towards more social relevance and of attempts to bring education closer to real life and its needs. This pragmatic view reflects an educational philosophy based on a scientific approach to the world, an approach which must form part of any educational programme.

In science education today, two major trends are evident: (1) integrated science teaching [1,2] (2) concern for the environment [3]. These often mean different things to different people but whatever view of integrated science is taken–coordinated, amalgamated, fused, combined etc. and whatever the limits of 'scope' and 'intensity' (See Chapters 2 and 8), the two trends are closely related. As examples, to which we still shall come later, we can mention the Russian teacher's guide book on nature conservation by B.G. Yoganzen [4] or the Resolution [71] 14 of the Council of Europe–Committee of Ministers "On the Introduction of the Principles of Nature Conservation into Education" [5].

Rutherford and Gardner [6] suggest that an integrated (unified) science course can be organised around at least four approaches (1) conceptual schemes (2) inquiry (3) relevance (4) process. Considering these approaches, it is clear that environmental education offers an ideal integrating concept for science teaching as well as for education generally, involving as it does all four approaches described. It relates actively to a wide range of general objectives of basic pedagogical importance promoted also through integrated science teaching, for example, active participation in the teaching process, the training of a critical mind, practical application of theoretical knowledge, education towards problem solving and decision making etc. On the other hand, environmental education itself needs integrated presentation.

What is Environmental Education?

The International Working Meeting on Environmental Education in the School Curriculum, organized in Nevada, U.S.A. by the Foresta Institute for Ocean and Mountain Studies, UNESCO, and IUCN (International Union for Conservation of Nature and Natural Resources), recommended the following definition:

> "Environmental education is the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the inter-relatedness among man, his culture and his biophysical surroundings. Environmental education also entails practice in decision-making and self-formulation of a code of behaviour about issues concerning environmental quality." [7]

During the past two years, this definition has been broadly accepted. Nevertheless, some reservations have been expressed by educationalists, who feel that it underlines too strongly a conservationist viewpoint and should be extended to include some purely educational benefits. There is no doubt however that conservationists, since the beginning of the movement, have always vehemently recommended education in support of their cause. At first they were concerned solely with conservation but later the scope and contents of their education programmes broadened; the conservationists were "turning away from secretive and inward-looking protectionism and becoming increasingly involved in education and countryside 'interpretation'" [Oswald 1971, 8].

The historical background for educationalists' involvement in environmental education comprised the "nature study" and "rural studies" popular in the early years of the century in the United Kingdom [Oswald 1971, 8, Fenwick 1972, 9] and many other countries, and also the development of "outdoor education" (learning in and for outdoors), in which the pioneering role of many voluntary, (and in particular youth) organizations in promoting field-trips, camping, children's gardens and other forms of activities, has to be recognized (compare also Passmore 1972 [10]. In the U.S.S.R. the concept of "krayevyedyenye" (exploring the native country), methodologically elaborated and broadly promoted and implemented during several past decades in geography and biology teaching as well as in out-of-school education contains many important elements on environmental issues. All socialist countries started in the early fifties to establish remarkable systems of "school gardens", "school-farms", "school forest-nurseries" etc. At first these were often biassed towards production targets and physical work but later they developed broader, less pragmatic approaches towards the environment.

Recently the 'environmental crisis' has been bringing conservationists and educationalists together. The expression 'crisis' is a somewhat journalistic description of the present disturbing state of the human environment, especially the natural one, and it implies a need for urgent, world-wide actions of conservation, improvement and wise management. Even authorities, organisations and individuals who did not much care in the not-too-distant past, are now committing themselves to the cause of environmental education. In some countries (Great Britain, the Netherlands, Sweden, Denmark, India for example) national bodies for environmental education have already been set up; in others this process has begun. Several countries have included environmental education in their national legislation, for example in the U.S.S.R. [11] and the German Democratic Republic [12] and in 1970 the U.S.A. passed a special 'Environmental Education Act' [13]. In the universities, teacher training colleges, pedagogical research institutes and other similar establishments, environmental education centres have been built up, concerned with various levels of education. The following are just a few of the many Institutions which are providing special courses in environmental studies and developing curricula, syllabuses and other programmes adapted to various areas and levels: the Universities of Georgia, Michigan and Wisconsin and numerous institutes, such as the Brenntree Environmental Center in Pennsylvania or the Institute for Ocean and Mountain Studies in Nevada in the U.S.A., Laval University and the Althouse College of Education in Canada, a whole series of establishments of higher education in Great

Britain (e.g. Aberdeen, Edinburgh, Huddersfield, Leicester, London, Southampton), the University of Tours in France, several Pedagogical Institutes (e.g. teacher training colleges) in the U.S.S.R. (Moscow, Sverdlovsk, Tomsk), as well as the Academy of Pedagogical Sciences in Moscow.

International organisations, both governmental and non-governmental, are also keenly involved in the stimulation and promotion of environmental education. The international interest became clear for the first time at the 1968 UNESCO Biosphere Conference [14], and was again much in evidence at the recent UN Conference on the Human Environment (Stockholm, June 1972). The Stockholm Conference discussed *inter alia* the exchange of information and the training of scientists in environmental sciences, and stated that:

> "The essentially interdisciplinary, humanistic and ethical aspects of environmental education—the science of ecology, planetary loyalty, respect for life, care for others and lack of all rapacity—should be stressed at every level of education and mass communication, so that all people develop a primary love for their fellow human beings and for their native planet." [15]

Among other international governmental organizations, the efforts in environmental education by FAO, OECD, and the Council of Europe deserve a special mention. Recently also the Council on Mutual Economic Assistance has endorsed a special programme on the "Elaboration of Contents and Methods of Environmental Education in Schools".

The International Union for Conservation of Nature and Natural Resources (IUCN), an international non-governmental organization with consultative status A with UNESCO has promoted environmental education particularly through its special permanent Commission on Education since 1949, and organized in December 1971 the first "European Working Conference on Environmental Conservation Education" in Rüschlikon, near Zürich, Switzerland. More than 100 people took part and, having stated that

> "*Whereas* environmental conservation education, under present circumstances of increased impact of man on the natural environment, has become a matter of urgent importance in all countries of Europe, and
>
> *Whereas* we recognize the aim of this education is to create a responsible attitude among the entire population towards the use and care of natural resources, and the protection of the environment as a whole against damage from pollution and other dangers."

reached the consensus that "the implementation of environmental conservation education should include the following activities:

- appropriate education and instruction in school courses at all levels;
- education and training in environmental matters in institutes of higher education of all kinds;
- out-of-school involvement of young people and adults in practical environmental conservation activities;
- in-service education and training of teachers and others concerned with general and out-of-school education such as youth leaders;
- the training of professional people concerned with environmental affairs, such as statesmen and administrators, as well as planners, architects, engineers and technologists;
- the education of the public at large by the use of mass information media and other methods." [16]

The above conclusions although specifically formulated with regard to the European scene have provoked much response and interest thus proving that they do express worldwide needs and general trends.

Environmental Education at Primary and Secondary Level

A. OBJECTIVES

The International Course for Teacher Training in Environmental Conservation and Education (organized by the IUCN, the Field Studies Council, and the Nature Conservancy at the Drapers' Field Centre, Betws-y-co-ed, Wales, U.K. 1972) [17] developed its work around three main themes, which at the same time represent three major approaches to, or rather stages of, environmental education:

(1) Teaching FROM the environment. This is a basic stage in the development of any programme in environmental education. Emphasis is on open-ended environmental work for which an essential requirement is that there should be no pre-conceived syllabus. The main concern is investigation and enquiry and the development of the learning process. Conducted mainly through field studies (both in rural and urban situations) it provides the pupils with first-hand experience and enables them to make their own investigations and draw some simple conclusions. It is most commonly used in programmes for younger children. Even if such a motivated field study is practised within one of the traditional teaching subjects (most commonly geography, biology, natural history, earth science), it obviously exposes the pupils to experience from other disciplines. A field trip to investigate a part of a creek will certainly draw attention to land-forms, rocks, soils, flora and fauna, vegetation, water, probably also microclimates, thus touching several disciplines (geography, geology, biology, chemistry, physics), and moreover presenting the various elements in their interrelation and interaction. Some human elements are sure to occur: settlements, water management, land use, maybe some pollution etc. So by the very nature of the exercise this will be interdisciplinary and around an integrating concept.

Some educators believe that environmental education means only field studies and that it must always be open-ended. They are mistaken. To omit field work and genuine investigation would be to neglect vital aspects but the direct use of the environment to promote the pupil's first-hand experience serves also to awaken his interest and contributes the first bricks towards the construction of a complex building of knowledge, understanding and appreciation. Many learning materials, techniques and environments are needed subsequently.

(2) Teaching ABOUT the environment. This is the second stage of studies based on a specific topic or a restricted area in which the main consideration is academic study to gain information and comprehension. Teaching about the environment certainly does not need to be restricted to field experience and can also be done in the classroom. Many of the field studies done at secondary level would fall in this category. This stage is also more sophisticated and does not rely on the pupil's own observation alone but is enriched by the teacher's leadership, preparation and evaluation of a field study in the class room etc. Through selection of topic or area the interdisciplinary features of such programmes are not eliminated, but are made more precise in certain aspects. A study of the differences between natural mixed deciduous woods and man-planted coniferous monocultures in temperate regions focuses on specific knowledge and understanding of botany, zoology, soil science, hydrology and climatology, may use techniques based on physics and chemistry, it relates to applied science (forestry)

through the problem of land-use and need in timber, to history and economics. Mathematics, geometry and drawing can be used in study and evaluation. Recreational and aesthetic values may be examined and thus link the programme with the humanities. Above all there are the important issues of interrelations in ecosystems, between living things and between them and their physical environment, and there is the impact of man on the natural environment, to show what can happen as a result of his activities.

(3) Teaching FOR the environment. Continuing in this direction, teaching tries to tell, how right, wrong, necessary or unnecessary a certain human interference has been. The teacher and his students have to interpret what should be avoided and what would be wise management. Will a forest plantation be appropriate or at least tolerable from the point of view of modern environmental conservation? Under which circumstances? And what are the other possible alternatives? So we arrive at this highest stage, where conservation, visual amenities, environmental quality and rational use of resources are the main objects.

The preceding stage leads the pupil some way towards problem recognizing and problem solving. This later stage takes these skills further and provides intellectual prerequisites for critical judgment and sound decision making. This is achieved through an integrated approach in which elements of several traditional science disciplines are used, investigated and confronted, and the criteria of applied science and technology as well as aspects of social sciences are taken into account, all at the level appropriate to the pupil's psychological development. Here, Piaget's, Bloom's and some other authors' cognitive levels are being found extremely helpful when developing environmental education programmes. Evidence and experience seems to indicate that a really cognitive education for the environment is applicable at a certain age, from perhaps 14 years of age upwards, which would include upper classes of lower secondary and the upper secondary (eventually high) school level.

It has to be emphasized that "conservation" is understood as "wise use and management". As Gladkov [18] pointed out very clearly, man does not have a series of discrete environments but one total environment in which the various components interact. Nothing would be more harmful than the old protectionists' "concept of two natures"—one small and protected including national parks and other protected territories; one large, not protected and only exploited. The principle task of a conservationist is not to try to make the share of "protected nature" larger, but to take proper care of the whole natural environment.

The International Working Meeting on Environmental Education in the School Curriculum (Nevada, 1970) [7] divided the curriculum into three stages:

I – Primary – approximately ages 5–10
II – Middle – approximately ages 11–14
III – Secondary – approximately ages 14–17

For each stage a major focus was selected, recognizing the developmental process in learning, as follows:

"Stage I–

Building basic vocabularies and skills leading to an appreciation and awareness of the varieties and similarities in the environment.

Stage II–

Emerging patterns and interrelationships of environmental features on local, national

> and world scales, concentrating on conservation and use. During this stage, particular attention is to be given to case studies illustrating representative man-environment problems.
>
> Stage III–
>
> Increasing perception of changes through time with particular reference to in-depth studies of environmental and social problems; in short, developing an environmental ethic."

There is a striking similarity between these three stages and the three themes; from the environment, about the environment and for the environment.

The 1970 Nevada Meeting also prepared a chart in order to give an indication of the content and objectives of an environmentally-oriented curriculum, to be adapted to different national and local situations in a variety of ways. This chart has been widely used as a model for an interdisciplinary, developmental programme in environmental education, and as an attempt to get away from traditional subject compartments. The content and objectives are therefore arranged according to various major environmental factors (the vertical component) in the three curricular stages indicated previously (the horizontal component of the chart). The scheme was further modified, new headings and content items added, at the first European Working Conference on Environmental Conservation Education in 1971 [16]. Nevertheless, to enable a basic orientation, we include the "Nevada Chart" in Figure 1, as it was published in the British journal "Your Environment" [19].

So the first requirement of any curriculum development: to define objectives–has been met. The question now is how to extend the framework that has been developed into a working curriculum. From the above it is clear that the objectives are broadly interdisciplinary and therefore their interpretation in the teaching process needs an integrated approach. It is also clear that they go far beyond integrating just the sciences since they involve in addition the applied sciences, technology, social sciences and humanities. A curriculum based on environmental science, with objectives as discussed above, is integrated from the start and has substantial advantages over a curriculum created by drawing disciplines together. Problems of the environment and problems involved in making man conscious of his environment through education represent some of the most urgent tasks facing mankind today. None can be tackled in isolation.

B. AN ENVIRONMENTALLY ORIENTED CURRICULUM

Until recently, when the "environmental crisis" shook the conscience of many people on our planet including educationalists and educators, the formal education systems only devoted a few lessons to conservation education. These were mostly in biology courses (natural history, botany, zoology) and mentioned protected natural features, such as national parks and nature reserves, nature monuments and protected species of animals and plants.

The irrelevance of this situation began to become evident in the years after the second world war, and several persons in several countries expressed the opinion that environmental awareness and attitudes should be recognized as one of the major educational goals of biology teaching and that environmental conservation education should pervade all biology teaching. Gradually the elements of integration between various biological disciplines (botany, zoology, somatology), between biological and earth sciences (geology, geography), and finally relations to other sciences (physics, chemistry) have been pointed out and it has been appreciated that environmental education offers opportunities to exemplify the interrelations. It was also felt that new methods and forms are needed: inquiry method, practical creative work of pupils, more field studies etc.

LANDFORMS, SOILS AND MINERALS

Knows that soil is dynamic:
(a) it forms
(b) it contains living things and supports plant growth
(c) it erodes

Can identify different kinds of landforms. Sees the interaction between landforms and living things. Can point out on a map the general arrangement of landforms in his country and the world. Can identify various mineral and energy resources and demonstrate the uneven distribution.

Knows how man accelerates processes of degradation and takes steps to ameliorate these conditions: strip mining, earth moving and sedimentation.

AESTHETICS, ETHICS, LANGUAGE

Builds a basic vocabulary of environmental terms. Names and classifies plants, animals, water features, soils, minerals. Acquires basic skills in using visual arts and music to express feeling for the environment in an elementary way.

Uses visual art, music and dance drama, language and photography to describe and interpret various environments. Appreciates how great artists and writers have perceived their environments.

Reacts to visual pollution. Has personal attitudes and habits reflecting a caretaker responsibility towards environment, and communicates this feeling to others.

PLANTS AND ANIMALS (BIOTA)

Knows from firsthand experiences various kinds of plants and animals in their own environment. Recognizes interdependence among soil, atmosphere, plants (producers), animals and man (consumers).

Can identify and explain a biological community in relation with its environment. Has a notion of the food chain and ecological balance. Recognizes the main types of biological communities and the impact of man on them. Is aware of endangered species, their importance and measures for their conservation.

Acts to create and preserve conditions under which ecologically balanced ecosystems can evolve.

ATMOSPHERE AND COSMOS

Can describe and measure climatic factors in the local environment. Recognizes the role of the atmosphere in the life of plants and animals (especially storms, evaporation and precipitation and fire).

Can identify and explain the major climate patterns of the world and relate these to vegetative patterns of the earth and economic activities of man. Observes the man-induced climate variations in a local area, noting air pollution and its effects.

Analyses and contributes to decisions affecting the quality of the atmosphere.

ECONOMICS

Relates food, clothing and shelter needs to available resources. Finds that specialization of labour increases efficiency.

Observes patterns in organizing resources with an emphasis on their rational use. (Agriculture and grazing, forestry and fishing, mining and manufacturing, transportation and communication.)

Works toward domestic and international solutions of environmental problems related to nutrition, poverty, transportation, waste disposal, source and distribution of energy resources.

WATER

Knows the necessity of water for life, and its importance as a natural resource.

Knows the water cycle and the various stages in the evolution of streams. Is familiar with the distribution of water on the earth and the general circulation pattern of ocean currents. Has an idea of the influences of water in the distribution of biological communities and how the distribution can be disturbed by pollution.

Analyses and contributes to the decisions affecting the availability and quality of water.

SOCIAL ORGANIZATIONS

Recognizes ways in which people organize themselves. Learns individual and group responsibility concerning environment.

Observes the relationships between political and natural boundaries. Sees the state as an agency for working on environmental problems. Recognizes international cooperation as a means of solving environmental problems.

Acts to alleviate environmental problems through laws, public policy and action programs.

AREA AND LOCATION

Experiences basic orientation within the local and national environments. Perceives the earth as the home of man. Observes how man uses and influences the environment.

Perceives the earth as of great magnitude but shrinking in terms of time, distance, and limits of resources. Knows the continuous interaction of man and biosphere.

Supports planning and research on wise land use and landscape management while opposing indiscriminate encroachment on open space.

PEOPLE

Recognizes the varieties and similarities among people. Knows how people live in and use different environments. Learns the interrelationships between beliefs and rituals and environment.

Sees population movements and settlement patterns as means by which cultural groups choose their environments. Discovers how people have used the same land in different ways at different times.

Uses data to interpret trends in population growth and distribution in relation to quality of life.

The Nevada Chart:

Developing awareness: nine categories of concepts and their establishment in three stages, as a growing individual undergoes an environmental education. (From the Final Report of the International Working Meeting on Environmental Education in the School Curriculum, IUCN, 1970).

As far as I know, one of the first attempts to incorporate conservation principles into a whole science course, was the 6th grade text-book of botany written by Professor Josef Sula of Czechoslovakia and published in 1959. [20] Throughout the course, every opportunity was taken to apply theoretical explanations to conservation. The disadvantage of that book was that the author restricted his conservationist approach merely to an aesthetic viewpoint. Subsequently large and famous British (Nuffield Science Teaching Project: Biology) and American (BSCS High School Biology–Green Version) programmes went further in environmentally oriented biology teaching based on more ecological approaches. Such biology courses with their ecological emphasis contain integrating elements and may be said to have an *orientation*, in this case an environmental one. Other orientations in which integrating elements can be detected include the molecular and the personal or medical but nowhere is integration more evident than in ecology.

C. COORDINATION BETWEEN EXISTING SUBJECTS

Biology was particularly mentioned as a subject (sometimes a group of more compartmentalized subjects), where environmental conservation teaching started and which always will remain one of the most important environmental "key disciplines".

But soon it was recognized that it would be a wrong solution to restrict environmental education with its recent wide scope to biology teaching only. An interesting opinion taking into account connection of school education with real life was expressed by Yogansen [4].

> "Unfortunately there is a viewpoint widely distributed amongst education authorities that the problems of conservation belong to the competence of the biology teacher only, whose duty it is to accomplish all the work and to bear all the personal responsibility for formulating a correct attitude towards the natural environment among the pupils. This viewpoint reaches far beyond schools and is shared by many industrial decision makers, engineers and other specialists who are not directly connected with biology and medicine."

Ian Hore-Lacy of Australia [21] pointed out the importance of long-term and in-depth coordination between various subjects (or coordination and combination in Blum's terminology) contributing to the integrating concept of environmental education:

> "In various parts of the world there are advanced courses now operating which are commendable in their concentration on field studies, ecology, pollution, population etc., but these are not a substitute for an integrated school curriculum which sets environmental objectives forward in its several subject areas, preferably as the main integrating factors."

R.A. Eden makes another important point when recommending that environmental education must

> "provide study in a very wide spectrum of subjects if it is to achieve the objectives set out in the IUCN definition" and that "Environmental education cannot be taught as a discrete subject, it is more of an approach, a 'synthesising concept' ". Although syllabus content is important, the method and approach should be the primary consideration, with the objective of establishing a learning situation concerned with principles, concepts, attitudes, values and skills rather than mere factual content." [22]

This is to say that environmental education does not in fact mean a separate branch of education. "It does not aim as much at instruction as it aims at approaches in interpreting the material, the knowledge." [23]

Let us now examine several representative examples of how this environmental integrating concept is being implemented in curriculum design in various parts of the world.

Yogansen and his colleagues in one of the U.S.S.R. centres of environmental education methodology in Tomsk thoroughly elaborated on environmental topics to be alloted to existing teaching subjects in Soviet secondary schools. Their recommendations, worked out in concrete details, involve civics and history, Russian language, literature, foreign languages, natural history, mathematics and drawing, physics and astronomy, chemistry, biology, geography, gymnastics, art and physical work. However elaborated their methodology may be, it remains at the stage of distributing contents and objectives among all subjects without emphasizing the cooperative relations between disciplines.

In Poland the identification of various topics related to the environment in and between different subjects is called *correlation.* The scheme reproduced in Figure 2 was presented by Dr. Danuta Cikhy to the 1972 IUCN East-European Seminar on Environmental Education in the School Curriculum. [24]

There are many interesting environmental education programmes in the U.S.A. The most usual plan of action is to get environmental education into the curriculum which now exists. This can best be done by producing appropriate textbooks and teachers' guides. In the late sixties, in co-operation with the State Department of Education in South Carolina and under the leadership of Dr. Matthew J. Brennan, a series of eight teachers' guides to conservation education, "People and Their Environment" [25] was developed. This work is unique in its complexity and includes a series of over 400 lessons relating science, social science, home economics and outdoor activities to the environment, all built around the same basic environmental concepts as the textbooks. The guides were written by eight teams of teachers, and are now some of the most widely used handbooks of their kind in the U.S.A.

	SUBJECT												
Major problems of environmental conservation in teaching subjects	biology			geography			hygiene	facultative work in biology/ chemistry	facultative work in geography/ economics	techno-logical education			civics
	form			form			form	form	form	form			form
	I	III	IV	I	II	III	IV	IV	IV	I	II	III	IV
preservation of species						x							
a) plants	x					x							
b) animals	x	x				x							
monuments of nature						x							
protection of the environment						x							
a) water			x	x		x							
b) air			x	x		x		x					
c) soil			x	x		x		x					
protection against noise pollution			x				x						x
national parks and nature reserves		x				x							
use of natural resources				x				x					x
environmental planning		x											
problems of food and agriculture					x				x		x	x	x

Figure 2. Inter-subjects correlation in environmental education in Polish high schools (Orig. Danuta Cikhy)

A real environmental curriculum reform has been recently accomplished in Sweden. During the autumn of 1968 the Swedish National Board of Education appointed a special Committee on Environment Education in Schools–the so called SMIL. Its task has been to "revise the curricula to provide a basis for efficient environmental education at all school levels" [26]. During the school year 1967/68 the Committee analyzed the structure of environmental education in various subjects and inquired into the teachers' opinions concerning future needs and possibilities. The Swedish concept is not one of a special subject in its own right, but of incorporation into several subjects such as geography, civics, ethics, history, chemistry, physics, general science and above all biology. For the 9th grade an integrated project "Our Environment in Danger" has been prepared. It is a team project common to all the above mentioned subjects. Other European countries have also started to consider the environment and teaching. A resolution of the Council of Europe's Committee of Ministers, adopted by the Ministers' Deputies on 30 June 1971, recommended the governments of the Member States to "introduce the principles of nature conservation and ecology into their educational programmes at all levels and in all appropriate disciplines" [5].

In Australia, the Australian Science Education Project (ASEP) for grades 7 to 10 develops the basic materials collated into units based on an environmental scheme to include most of the educational objectives equivalent to stage two on the "Nevada Chart". Ian Hore-Lacy writes:

> "Whilst it is increasingly recognized that traditional subject divisions and teacher deployment usually lead to repetition, overlap, omissions and fragmentation of knowledge and experience, few schools or education authorities seem to be tackling this problem in any depth. The increasing demands within each subject as well as the newly-recognized necessity for achieving an integrated and life-related understanding of the total environment are becoming a powerful stimulus for rethinking in this area however, and for a rationalization of resources, using new methods in classroom, laboratory, and field." [21]

So, through different degrees and stages of integration, progress is being made towards the development of curricula based on concepts of the environment.

D. INTEGRATED COURSES

Some educationalists seem to think that environmental education cannot be effectively provided by schools, unless taught as a separate teaching subject. One of the main arguments put forward is the view that environmental education as a coordinating and integrating concept pervading the entire school curriculum is not easy to accomplish. The task obviously is not an easy one, but I believe that the efforts at present being made to tackle it are right and relevant.

It is however highly desirable to introduce in the upper forms of secondary school, a really integrated course, revolving round major topics involving environmental concepts, e.g. within the stage III of the "Nevada Chart". Such a short experimental course is now being introduced in the last form of the secondary schools in the U.S.S.R. The idea was described by V.A. Popov:

> "This course should synthetize all knowledge on nature conservation obtained by schoolchildren at school and give them an idea about the unity of nature, about the interrelation and interdependence of all components of natural complexes, and about nature's severe responses to the arbitrary violation of its laws by man." [27]

The syllabus of this course "Major Problems of Biosphere Conservation" is designed for 20 lessons (hours) and includes 10 themes:

1. Interrelation and interdependence in nature;

2. History of the development of environmental conservation;
3. Renewable and non-renewable natural resources;
4. Conservation and use of mineral resources;
5. Soil fertility as a basis of the prosperity of our country;
6. Air conservation;
7. Vegetation and its role in the biosphere;
8. Diversity of animal life and its role in natural complexes;
9. The main means and forms of environmental conservation;
10. The main problems of the conservation of the biosphere.

Apart from other important features, this course also provides, through its biosphere approach, a global environmental awareness, which is another important objective of environmental education.

A more comprehensive and sophisticated "A" level syllabus for the abler sixth formers was constructed by a group of teachers in Hertfordshire, England, under the leadership of S. McB. Carson [28]. It is designed in four sections:

1. Processes and Systems of the Natural Environment and the Limits of the Resources Base (100 hours);
2. The Ecosystem (80 hours);
3. The Interaction of Man and the Environment (80 hours);
4. Environmental Pressures and Planning–A Field Study.

The last section should involve the pupil in making his own observations in the field, and the student will be expected to select one topic from a given list.

E. METHODS, FORMS AND FACILITIES

As already indicated above, combining environmental education with integrated teaching requires the development of innovative methods and forms, for which again special facilities are necessary. In the first place *field studies* are extremely important. As every pupil has to have direct contact with the features and processes of the environment, outdoor education has as vital a contribution to make in environmental education as it has in integrated science teaching. Not by chance has one of the starting points of present environmental education development in the United Kingdom been the work of the Study Group on Education and Field Biology whose report was published in 1963 [29]. One of the first results of Swedish environmental curriculum reform was a tremendous development in outdoor activities. One interesting project involved the formation of non-graded working teams from pupils of grades 7–9 who worked happily and successfully together in the open air.

Field studies may include short excursions (several hours–half a day–full day) to various places of interest as well as regular observations of a special outdoor area close to the school. Usually the incorporation of a longer outing into the compulsory teaching time presents problems. Therefore the 1971 European Working Conference on Environmental Conservation Education recommended that

> "every school should have suitable nature study areas attached to it or within easy access, and that, in the development of new schools, specific provision for such facilities be incorporated at the planning stage" [16].

The use of such areas (mostly in the form of school-gardens) at the schools in socialist countries has already been mentioned above.

Other opportunities are provided by residential centres, where whole classes or selected groups of pupils spend a longer time during the holidays or even within the school term. The United Kingdom has a whole network of such residential centres operated by various organizations. The establishment of the Field Studies Council has already become a classic example and serves as a model for similar developments in other parts of the world. A slightly different concept of field centres arises in Israel and a whole series of residential centres in the U.S.A. and Canada offer interesting programmes for various levels in various areas of field studies. Field studies also lead to the *active participation* of the pupils. A well prepared study develops in the students an ability to ask questions and to design investigations, to evaluate their findings and their own procedures both indoors and out-of-doors, to discuss freely and to use creatively laboratory and library resources.

In the German Democratic Republics integrated science teaching in secondary schools takes the form of homework on some topic-oriented task the results of which are then discussed during school lessons. Professor R. Hundt describes interesting examples of such a task: "The optimum use and conservation of soil", where weeds are used as indicators of soil quality and fertility in confrontation with land use practised by agricultural cooperatives, or where the soil erosion and its impact on the crops is explored. [30,31,32]

Such experience is related to actual problem solving and to environmental improvement in the local community, and can mean not only the *pupil's involvement* but that of his family as well. Field studies can bring about a broad liaison between school education and out-of-school activities, in fact many innovative forms and methods now accepted by formal education have been pioneered by voluntary out-of-school organizations.

Conclusion

The present paper is focused on the primary and secondary school levels. Some questions remained unmentioned or were not dealt with in any depth.

Space does not allow the introduction of the problems of tertiary level, teacher training in particular*, which represents one of the most important components of environmental education. Out-of-school education could also only be briefly mentioned, although its importance in environmental education is an immense one.

This paper has tried to show the importance of environmental education, to suggest some ways of implementating it in school and to point out its close relation to integrated (science) teaching forming as it does, a major concept for a unified approach.

In spite of all the promising developments in progress, school authorities are mostly rather conservative organizations, and the desirable changes do not proceed smoothly and quickly enough to always keep pace with urgent needs of the boisterous development of human society.

I would like to conclude with words of Mr S.T. Broad, President of the British Association of Education Officers, who said in one of his speeches in 1969:

> "The concept of the conservation of nature and natural resources should merit recognition in a permanent role as a co-ordinator of the curriculum in our schools.

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* A future 'New Trends' volume will be devoted to teacher training for integrated science.—Ed.

I believe that this should no longer be disputed and that the value of such basic education in achieving an integration of subjects, in bringing some kind of unity to the learning process in the minds of the learners is a justification in itself. Moreover, for teachers to defer for much longer the acceptance and implementation of environmental studies as a basic requirement for all pupils could be tantamount to committing suicide, because the loss of the natural environment of this world for the generations to come is unlikely to be replaced by acceptable environments on the moon or on Mars."

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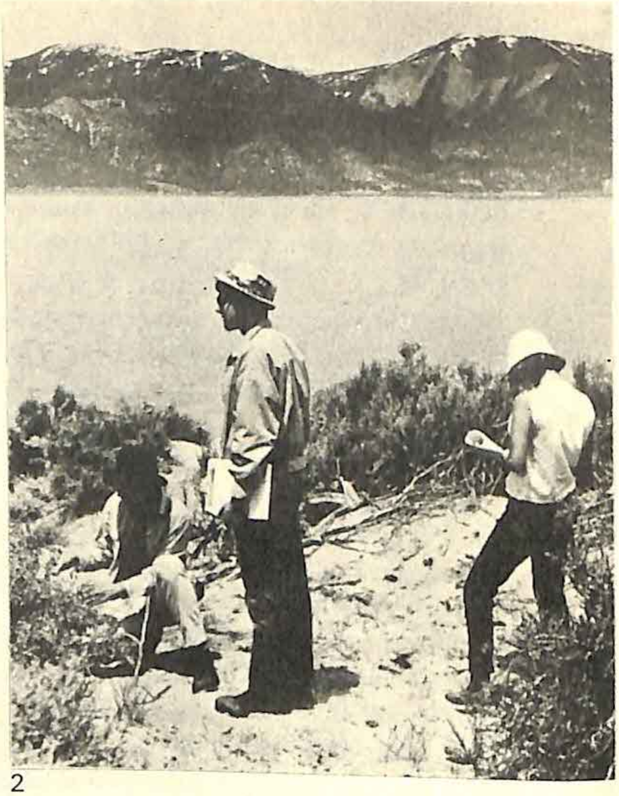

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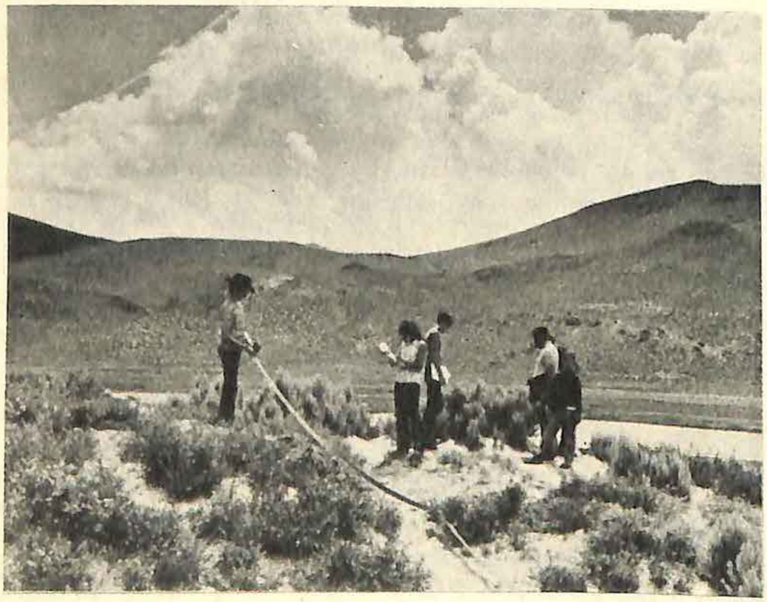

1. A young conservationist group exploring a virgin forest nature reserve in Middle Bohemia, Czechoslovakia.

2,3. Ecological field studies conducted at the Foresta Institute for Ocean and Mountain Studies, Nevada, U.S.A.

Chapter 8

EVALUATION OF INTEGRATED SCIENCE CURRICULA

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Summary

Traditionally curricula have been judged in terms of course content. Today's integrated science curricula have much wider aims and objectives (see Chapter 1) and call for new kinds of evaluation techniques and instruments.

Three stages of evaluation can be distinguished (1) the *reflective* which takes place in the early stages of curriculum building and can help to decide *inter alia* what qualifies for inclusion as integrated science (2) the *formative* which is an on-going evaluation of the many curriculum components and involves feedback and adjustment of approaches and materials (3) the *summative* stage in which data are gathered about the quality of the curriculum after it has been implemented.

Examples from integrated science teaching schemes are given and suggestions are made for future developments in evaluation procedures.

The key to successful integrated science teaching is the quality of the curriculum upon which it is based. The link between the educational planner and the learner is provided by means of that curriculum. A curriculum is a plan which incorporates:

a set of objectives;
learning experiences–including teaching strategies, pupil activities, and learning materials which may be sequenced or interrelated; and
evaluation procedures adopted for students [cf., Taba, 1962].

Curriculum evaluation is concerned with gathering, analysing and reporting data, in order to improve decisions about these components. It is concerned with improving the *quality* of curricula through the question: "How effective are the curriculum components?" Some aspects cannot easily (if at all) be measured, and in these circumstances, subjective judgements may need to be made.

In this sense, curriculum evaluation contrasts with the type of evaluation of students characteristically used by classroom teachers. Procedures used by classroom teachers tend to be restricted to pencil-and-paper tests. Such techniques are deliberate attempts to reduce subjective judgements, as objectivity is important to reduce possible bias where the prime purpose is to grade students. On the other hand, value judgements involving subjective decisions constitute the essence of curriculum evaluation.

This chapter describes techniques for improving the decisions required for curriculum evaluation. Data in the chapter is derived from many sources. The use of *all* techniques described is neither necessary nor even desirable, under many circumstances. In fact, probably no single curriculum has ever been evaluated using the full range of techniques described. Limitations upon human and physical resources, and on time, often impose limitations upon what techniques can be used. Procedures selected should suit the particular set of decisions to be made, such as whether the curriculum has an effect upon enrolment trends, costs of implementation, student personality variables, classroom teaching practices, or student interests and attitudes. Consequently, there is no uniquely "best" approach to evaluation, nor is there a set of rules. Many alternatives are available. Selection must be made from these alternatives based upon relevance, practicability, judgement and experience—and even a measure of intuition.

This chapter will:

(1) review some emerging trends in curriculum evaluation in general, and in science curriculum evaluation in particular;

(2) describe, and explain the methods involved in each of the three stages of curriculum evaluation as related to integrated science curricula: note: these stages are known sequentially as reflective, formative and summative evaluation;

(3) suggest some directions for future developments in the evaluation of integrated science curricula.

Emerging Trends in Curriculum Evaluation

Traditionally, curricula have been regarded as course content documents written by one or more people (generally teachers). These documents have been circulated to all other teachers in the area, state or nation for implementation. With notable exceptions, it has been unusual to conduct curriculum trials or pilot studies, and consequently the concept of obtaining feedback as a basis from which to revise curricula has been rare. Where curriculum evaluation has been conducted, it has usually been in the form of obtaining student achievement test scores after the curriculum has been fully implemented. These traditional evaluation procedures have been criticised. A major criticism has been that they rely too heavily upon "sophisticated statistics poised upon techniques of rustic simplicity" [Hudson, 1966:3].

Recently, increased investment of public funds in curriculum development has led to demands to provide evidence that the funds are being effectively spent. Cost benefit analysis techniques have been applied to curriculum evaluation. A stumbling block to this approach has been the inability to measure "output" from curriculum with any confidence in the validity of the measures. However, there are changes in curriculum evaluation procedures, and some of the trends are described below [cf., Atiyeh, 1969:44; Sand, 1971:241].

(1) Changing emphases in techniques for student evaluation

Curriculum evaluation has relied heavily upon the evaluation of student achievement. Consequently, changes in the nature of techniques used for evaluating student progress have implications for curriculum evaluation. These techniques are becoming increasingly oriented towards diagnostic and mastery purposes, and away from competition and grading purposes. These new purposes seek to diagnose causes of individual difficulty and to establish when a student has learnt a particular amount. Thus, evaluation procedures for students are reflecting individualization of learning experiences, their sequencing and the rates of completion. Measures more closely related to objectives (criterion-referenced indices) are increasingly being used. [See, for example, fuller discussions in Ebel, 1971:282, and Block, 1971:289].

(2) Diversification of procedures

The range of evaluation techniques and instruments has been increased, and now can encompass a wider range of objectives. Thus, tests of higher level knowledge-related (cognitive) abilities (such as ability to analyse and synthesise knowledge), tests of student preference for particular ways of deciding between knowledge-related alternatives (cognitive preference tests), of attitudes (affective tests) and ability to conduct laboratory experiments (performance outcomes) are increasingly being developed and trialled in several nations, including U.K., Australia and New Zealand. The heavy reliance on pencil-and-paper instruments is also being progressively reduced. Oral examining retains emphasis in Germany, Russia and the U.S.S.R.; open-book and take-home exams, as well as techniques formerly regarded as being solely for the psychologist (such as evaluation of self-concept and creativity) are being used experimentally by some teachers; laboratory simulation evaluation techniques have been used in computer-assisted situations. Systematic observation of what happens in science classrooms is being promoted as classroom interaction studies are extended. These approaches complement achievement tests comprising largely objective items (whose administration and scoring facility have provided seductive appeal to administrators responsible for large-scale testing).

As was pointed out by Karplus [1968:1], curriculum evaluation "is different things to different people". Related to his Science Curriculum Improvement Study [S.C.I.S.], Karplus presented six diverse approaches. These approaches exemplify the diversity of procedures which are possible, even related to one curriculum project. They include reactions of children and teachers to curriculum units, observations of and consultations with children and teachers, and studies of student needs and interests in relation to the impact and utilization of the S.C.I.S.

Procedures may range between the formal test-orientated situation with samples numbering a few at one school, or many at many schools, to the chat with one teacher or the discussion at a staff gathering at a school, at which there is no formalized instrument or even structure for discussion.

(3) Changing Organization

School-developed procedures are replacing statewide and national evaluation procedures which tend to create curriculum uniformity and stifle diversity. Moderation systems may then be superimposed to facilitate comparisons between different schools or systems. School-conducted evaluation has promoted co-operative and cumulative evaluation, replacing "one-shot" end-of-course examinations. [Wiseman and Pidgeon, 1970; Christopher, 1972:3].

(4) Increased differentiation between stages of curriculum evaluation

Curriculum evaluation activities conducted before, during or after curriculum development and implementation are known respectively as reflective evaluation, formative evaluation, and summative evaluation.

These three stages provide a systematic basis for studying curriculum evaluation procedures. For purposes of convenience, these three stages will be treated separately in this chapter. The reader is cautioned, however, that the stages do not represent watertight compartments. In fact, there may be considerable overlap between the procedures and instruments used for each of the stages.

Stages of Curriculum Evaluation Related to Integrated Science Curricula

The characteristics of each of the three evaluation stages will now be described and discussed, and illustrated with examples of curriculum components selected from integrated science curricula [see also Bloom *et al.*, 1971].

Reflective evaluation comprises a preliminary screening of curriculum components to decide on their suitability. It is based upon subjective evaluation, often including insight and hunches.

Judgements may also be improved by the use of the opinions of consultants. Such judgements might relate to such questions as:

> Are the objectives "good"—serving the individual, the society and the discipline?
>
> Are the learning experiences appropriate to the cultural context?
>
> Is the use of "Test A" valid to provide evidence of the development of critical thinking ability?

Such questions may be solved on the basis of evidence derived from many sources including philosophy, sociology and psychology.

Applying reflective evaluation to integrated science curricula at the most basic level, we may examine the compatibility of "integration" and "science". The concept of integration in science teaching may also be examined, on the grounds that man's mind has differentiated science into its "branches", or because it may be a pious hope ever to *achieve* integration in science, or because too much is lost in the union.

The compatibility question requires a consideration of what is meant by science, viewed against what is involved in integration, and with a study of the extent to which science and integration can be reconciled. There has been a proliferation of definitions of science. Conant [1957:54] defined science as "an interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation". Common to this and many other definitions of science is the reference to experimentation involving observation, and the subsequent organization of interrelated concepts into an ordered theoretical structure.

As with many others, Conant's definition implies both a "product" component in science (concepts, principles, "big ideas") and a "process" component (experimentation, observation, and other procedures). [For a fuller discussion of this issue, see Longstreet, 1971:261]. The reflective phase in evaluating integrated science curricula includes decisions about the appropriate "blend" of Conant's scientific "process" and "product" components—key decisions [cf., Koertge, 1969:26].

Reflective evaluation can also be used as a strategy for evaluating the usefulness of integrated science in fulfilling overall education objectives. In this respect, participants at the recent Asian UNESCO Regional Workshop on Integrated Science Teaching considered that integrated science teaching could best fulfil the needs of the majority of children in Asia, whose educational opportunities are largely limited to primary schooling. The resultant report [UNESCO 1971:3] states that:

> "attempts are being made to devise science courses in which concepts of science are developed in a way appropriate to the child's experience and level of development, so as to reflect the fundamental unity of scientific thought. Such integrated science courses aim to present science in a coherent way, and to avoid premature or undue stress on the distinctions between the various scientific fields. They emphasize the underlying methodology and processes which characterize the scientific outlook. By a judicious choice of experiences and activities, children learn how to think productively about the natural world and man's interaction with it by calling upon knowledge and skills from the various parts of science as needed."

Reflective evaluation may be used to clarify the definition and to refine the criteria for deciding what qualifies for inclusion in integrated science curricula. On the basis of his analysis of the vast literature of integrated science, d'Arbon [1972] has prepared an annotated bibliography of thirty-four definitions. He has also examined distinctions between definitions of integrated, unified and fused science. These definitions formed the basis of a questionnaire circulated for judgements by an international jury of knowledgeable "integrated science" educators. d'Arbon has synthesised the selected, relevant components of the responses, and obtained a definition of integration from these reflective evaluation procedures, namely:

> " 'Integration', when applied to science courses, means that the course is devised and presented in such a way that the student gains the concept of the fundamental unity of science; the commonality of approach to problems of a scientific nature; and is helped to gain an understanding of the role and function of science in his everyday life, and the world in which he lives."
>
> "Such a course eliminates the repetition of subject matter from the various sciences and does not recognise the traditional subject boundaries when presenting topics or themes."

Application of Reflective Evaluation Techniques

The application of reflective evaluation techniques to each of the curriculum components may be easier given a checklist or rating scale. A "graphic" rating scale based upon consensus concerning the key characteristics of integrated science (in part derived from the study of d'Arbon) is presented in Table 1 on the following page, and may be used in reflective evaluation of the examples which follow. Each rater draws a cross on each axis at the point indicating a personal evaluation of the curriculum dimension being rated.

This graphic rating scale may be applied in part or whole by the reader wishing to engage in reflective evaluation. It may be applied to the reader's own situation, or to any situation purported to be an integrated science curriculum. Reflective evaluation techniques may be used to screen curriculum components (objectives, learning experiences and their organization, evaluation techniques) prior to classroom trials. They may be applied in large-scale formalized situations (e.g., in national curriculum projects in conjunction with specialist evaluators), or in a single school—perhaps even informally—by one or more teachers developing a curriculum on a part-time basis. They may result in day-to-day modifications during curriculum development. Unfortunately, few people have documented their reflective evaluation procedures; so that, although the product (in the form of a modified curriculum) is available, evidence of the stages by which it was reached, including the failures, as well as successes, cannot be explored.

The types of questions which may be resolved during reflective evaluation are illustrated by the following:

> Is the curriculum objective "observation of similarities and differences between two leaves" appropriate for the age group, socioeconomic group, or in the cultural context in which students may live?
>
> Have fifth grade students reached the appropriate stage of concept development to be able to profit from a learning experience involving observations of volume changes during solution of solids in liquids?
>
> Is the use of the "Test of Understanding Science" likely to relate to the attitude objectives of an integrated science curriculum?

Initiative must be taken to identify crucial questions relating to each of the curriculum components. Reflection upon these questions, against the background of relevant evidence, has the potential to improve the resultant curriculum. This reflective stage of evaluation is quite a crucial one, and yet fewer resources have been devoted to its application (or to improving the stage) than to the later stages of evaluation. This is despite the consequences of proceeding to produce a fully-fledged curriculum or curriculum unit with its related materials. With all the costs of preparation and printing, subsequent changes are likely to be either costly or cosmetic!

Table 1: Graphic Rating Scale for Reflective Evaluation of Extent of Integration in Science Curricula

Dimension	Extent of Integration Reflected*
1. Objectives reflect fundamental unity of science	NEI SI
2. Objectives reflect commonality of approach to problems of a scientific nature	NEI SI
3. Learning experiences relate to the role and function of science in everyday life	NEI SI
4. Learning experiences do not duplicate subject matter from various sciences	NEI SI
5. Learning experiences provide links between content from two or more traditionally separate sciences	NEI SI
6. Learning experiences provide opportunity for students to engage in processes which cut across traditionally separate subject boundaries	NEI SI
7. Considered overall, evaluation procedures tap whether students can bring together bodies of knowledge from traditionally separate sciences in order to seek a solution	NEI SI
8. Evaluation procedures seek data about "scientific" ways of thinking in seeking solutions to problems	NEI SI

* NEI = No evidence of integration
SI = Substantially integrated

In summary, reflective evaluation of integrated science curricula

(1) can help to resolve basic decisions, including the compatibility of science and integration, and the relative blending of "process" and "product";

(2) has the potential to improve decisions about each curriculum component;

(3) is conducted before classroom trials in order to provide preliminary evidence about the quality of a new curriculum;

(4) is based upon subjective reflection by evaluators, including teachers, and consultants if available. Questions devised intuitively are pondered on the basis of any relevant data, and decisions are based upon evidence, using experience and judgement to interpret the evidence.

Formative evaluation comprises the gathering and interpretation of data about the quality of curriculum components, units or materials while the components are still exploratory and fluid (i.e., evaluation during pilot trials at the developmental stage) [cf., Bloom *et al.,* 1971]. It may lead to decisions to revise any aspect of the curriculum, such as the objectives [cf., Eggleston and Kerr, 1969:16–25], the nature of the student learning activities, the strategies of the teachers, and the curriculum materials.

The pilot trials of integrated science curriculum units and materials during development may provide data through direct observations of classroom effects, through interviews and questionnaires to provide feedback from trial teachers or researchers, and through the use of checklists, attitude scales, and tests administered to students, teachers and administrators. These data may be related to the past experiences of teachers and students and to what happens in the classrooms [cf., Grobman, 1970:185].

Formative evaluation is primarily used to assist in the revision of a trial curriculum unit or trial curriculum materials. Thus, the procedures used in formative curriculum evaluation should be much broader than pencil-and-paper tests (as useful as these are for providing part of the data). For example, there is increased recognition of the usefulness of observational systems for providing data about the curriculum influences upon teaching methods, student performances, use of laboratories and apparatus, and other variables [Rosenshine, 1970:288]. But few curriculum evaluators have reported the use of observational systems [Welsh, 1969:439].

Formative curriculum evaluation is likely to have greatest impact when the evaluative data relates to areas identified by the curriculum development and revision team as requiring revision. Australian Science Education Project (A.S.E.P.) revisions have been notably influenced following site visits by teams jointly involved in the development and evaluation of the A.S.E.P. curriculum materials.

Techniques employed in the formative curriculum evaluation of a number of national American curriculum projects are listed in Table 2[Welch, 1969:431].

Table 2: Formative Evaluation Techniques listed in Major American National Curriculum Projects

Type of Formative Evaluation Activity Reported	Number of Projects
Teacher reports (written and verbal)	26
Classroom visitation	15
Student interviews or discussion	9
Questionnaires (structured)	7
Test results	4
Videotapes of classes	3
Professional view of produced materials	2
Computer assisted instruction	1

Depending upon the availability of resources, appropriate techniques must be selected to suit the context.

An example of the use of formative evaluation procedures within one project is provided by A.S.E.P. This is a four-and-a-half year duration curriculum materials development project, which has employed the equivalent of a team of four full-time evaluators for three of these years—a resource which very few evaluation groups could hope to have available. A.S.E.P. has produced trial units for potential adoption in all six Australian states. In its approach to formative evaluation, A.S.E.P. has sought a wide range of feedback data during the developmental stages of each unit.

Such data have included responses to questionnaires and inventories by students, teachers and outside experts (such as educators, psychologists, and other academics), and student results on various tests (see Table 3).

For example, teacher evaluation booklets are provided for completion by teachers during classroom trials of each unit. These booklets seek ratings upon twenty-four items on a five-point scale, from "1" (very favourable impressed) to "5" (unsatisfactory), with additional space provided for comments where desired by respondents. Some aspects for rating are:

(a) the typography, readability and cartoons in the student materials;
(b) the layout and information contained in the teachers' guide;
(c) the name and overall structure of the unit, the stated objectives of the unit, how the unit reflects the A.S.E.P. aims, its relevance to the environmental scheme, and its appropriateness to the specified conceptual stage of development.

Table 3: Descriptions of A.S.E.P. Instruments

Stated Purposes of A.S.E.P. Instruments	Nature of Items included in A.S.E.P. Instruments
Teacher Information 1a Questionnaire "to sample teachers' opinions and preferences about teaching science in the classroom"	Multiple choice responses categorizing teacher experience, school science teaching conditions
Unit Evaluation 1a Questionnaire to obtain feedback on the second specifications of A.S.E.P. units	Series of headings to obtain open-ended feedback on several aspects of A.S.E.P. units (e.g., relation to A.S.E.P. aims; relevance of main ideas to A.S.E.P. environmental scheme, content and nature of science, Piaget levels, inquiry approach, terminology, teaching approach, etc.)
Unit Evaluation 2a Questionnaire seeking teacher ratings and comments on student and teacher materials, and aspects of units	Twenty-four five-point opinion ratings, and aspects for comment (e.g., layout, appeal to children, name of unit, overall unit structure etc.)
Unit Evaluation 3a Questionnaire seeking data from "several categories of evaluators" (including academics, interested groups) teachers, outside evaluators	An extension of Unit Evaluation 2a (and largely supersedes it) incorporating also ratings on "matters basic to A.S.E.P. philosophy" (including relevance to A.S.E.P. aims, adherence to content selection criteria)
Unit Evaluation 4a Questionnaire seeking data specifically related to individual units, jointly developed by the A.S.E.P. Unit Materials Development Officer and the A.S.E.P. evaluation section	Variable, relating to specific problems within particular units.
Unit Evaluation 5a Questionnaire seeking student opinions about and activities undertaken during A.S.E.P. Units	Inventory of strength of student interests and activities (five-point scale, 28 items); preferences for classroom activities (e.g., teacher-or materials-based instruction, grouping, interest value of A.S.E.P. materials), and opinions about difficulties.

The extent and effects of formative evaluation data upon the A.S.E.P. unit "Mice and Men" is summarized in Table 4. This unit is described as a "Stage 1" unit (i.e., in A.S.E.P.'s terms, approximating to Piaget's concrete stage). The objectives sought for students are that they:

(i) learn two defining characteristics of mammals;

(ii) become aware of the diversity of mammals and of the similarities and differences between humans and other mammals, particularly mice;

(iii) act responsibly when entrusted with the care of small mammals;

(iv) be more effective in communicating with others through working in groups and discussing their findings.

The recommended student learning experiences included: sexing mice, weighing and measuring, graphing, making observations, and recording their findings in tables.

Table 4 illustrates the effects of feedback from State Advisory Committees, teachers, students and outside evaluators. Among changes resulting from formative evaluation were reduction in number of booklets, improved quality of photographs and layout, more detail given in Teachers' Guide, and the inclusion of more difficult test items. The reasons for rejection of some of the other suggestions are not known.

Table 4: Nature and Influence of Formative Curriculum Evaluation Upon the A.S.E.P. Unit "Mice and Men"

Comments and/or Recommendations	Sources of Comments	Actions Taken During Revision
1. Presentation		
Too many loose bits. Booklets too thin.	S.A.C.* Teachers, outside evaluators	7 Booklets and 14 worksheets reduced to four booklets
Poor reproduction of photographs	S.A.C.—trial teachers, outside evaluators	Slight improvement to a more uniform standard
Presentation cramped, lacking variety—headings barely distinguishable	Outside evaluator	More spread out, more variety. Headings and sections more distinguishable
Comic mouse overdone	Outside evaluator	Less use of cartoon in national trial, though retained
2. Organisation		
Needs to have statements of relationships of this unit to other units	S.A.C.	Links added in Teachers' Guide
3. Assistance to Schools		
Asterisks for most useful reference books	S.A.C.	No action taken
Add prices of reference books	S.A.C.	Added to student reference books
4. Assistance to Teachers		
Include a breeding timetable for mice	S.A.C.	Added in Teachers' Guide
5. Learning Experiences		
Add a flow-chart to give students a clear overview of the whole unit	S.A.C.	No action taken
A visit to the zoo is a much better introduction or a display of live or preserved mammals or film	Outside evaluator	No reference made to this suggestion
A set of large black-and-white photographs or colour slides could replace Booklet I (Mammals)	Trial teachers	No action taken
Use of Australian animals preferred	Outside evaluator	Included kangaroo. There was already echidna, koala, platypus. These were in the context of their natural habitat
Contrasting Comments—Booklets disliked in general (doesn't get any message across). On Grade 7—10 students the photos aroused considerable interest	S.A.C.	Revised version of "Mice and Men" sought to reconcile these comments
6. Evaluation		
Test is not challenging enough for the brighter students	Trial teachers	Questions 8,9 and 11 in national trials had higher levels of difficulty and increased discrimination
Include sample items for tests	Outside evaluator	Helpful suggestions for evaluating objectives included in Teachers' Guide

*S.A.C. = State Advisory Committee (Note: These comments are from Committees in at least one of the six Australian states).

Further examples of feedback from the A.S.E.P. formative evaluation stage of the "Mice and Men" unit follow:

> On a five-point rating scale, a sample of 100 students indicated that they "liked very much" the diagrams, photographs, and worksheets, but were neutral about the test. In a sample of 268 students, 54 found the unit "easy to read" and 44 "about right". 34 students "liked most" handling the mice, 48 "disliked most" cleaning the cages. The students reported no major areas of difficulty, and 95 of the 268 could now breed and handle mice (which they couldn't do before), and 124 reported knowing now about mice and their care (whereas they didn't know before the Unit was studied).

Quite apart from the extensive written feedback obtained during formative evaluation from students, teachers and consultants (from tests and questionnaires), substantial and equally helpful evaluation data may be obtained from classroom visits, where depth discussions with students and teachers as well as observations of classroom activities—often subjective and intuitive—provide valuable alternative and supplementary data.

Experiences of formative curriculum evaluation are also provided in the British project known as the Schools Council Integrated Science Project [S.C.I.S.P., 1971]. Their evaluators used a combination of written papers, detailed teacher assessments, student attitude questionnaires and opinion polls (self ratings, from "hopeless" to "excellent" on memory, text interest, etc.), direct student interviews, team moderation and "global" assessment by teachers, applied to thirteen objectives related to knowledge, attitudes and skills. (see Table 5).

Table 5: "Aims" and "Assessment Procedures" Used in the Schools Council Integrated Science Project**

Assessment Procedure	Aims												
	1A	2A	3A	4A	1B	2B	3B	4B	5B	6B	1C	2C	3C
1. Written Paper	/	/				/		/		/		/	/
2. Detailed Teacher Assessment	/			/		/	/	/			/		/
3. Pupil Opinion Poll				/		/			/	/			
4. Direct questioning of pupil	/						/				/		
5. Team moderation	/						/						/
6. 'Global' assessment by teachers	*	*	*	*	*	*	*	*	*	*	*	*	*

** Footnote The numbered aims correspond to the following abbreviated descriptions:

A. Knowledge

1A	To recall, understanding.
2A	To understand the importance of patterns and to be able to apply these.
3A	To be able to recognize scientific problems.
4A	To understand relationships of science to development and recognize its limitations.

B. Attitudes

1B	Faithful reporting.
2B	Concerned for applying scientific knowledge within the community.
3B	To have and be willing to pursue scientific interests.
4B	To be willing to make probability-based decisions.
5B	To be willing to search for, test, and use patterns.
6B	To be sceptical about suggested patterns.

C. Skills

1C	To work independently and as part of a group.
2C	To discover and use available resources such as books, apparatus and materials.
3C	To handle and communicate ideas.

Arising from statistical analyses of the evaluation feedback [S.C.I.S.P., 1971:22] from as many as 950 students, recommendations for S.C.I.S.P. revisions included rewriting of a number of test items and modification of the initial statement of aims.

In summary, formative evaluation of an integrated science curriculum

(1) has potential to improve decisions about each curriculum component;
(2) is conducted during classroom trials to provide data upon which revisions of curriculum components may be based;
(3) is based upon evidence obtained from students, teachers and outside evaluators, and from the use of tests, questionnaires, inventories, rating scales, interviews, classroom visits and the use of systematic observation systems.

Summative evaluation comprises the gathering and interpretation of data about the quality of a curriculum *after* the implementation either of the completed curriculum or curriculum unit, to explore the overall effects of the curriculum. Summative evaluation seeks to provide a broad, systematic, terminal appraisal of a curriculum in operation, in relation to its overall objectives. An evaluation grid with cells which relate each objective to each aspect of content, represents a systematic approach which may be used at the summative evaluation stage. Evaluation instruments may then be selected or developed for each cell. Although A.S.E.P. and S.C.I.S.P. have used a range of instruments, such a broad-spectrum approach to evaluation of science curricula is rarely used in practice [cf., Cohen, 1963]. In general, local initiative and the availability of resources will determine the extent of curriculum evaluation that is possible. It is therefore promising to see the growing emphasis upon broader-based curriculum evaluation activities in the context of integrated science curricula. For example, in Sierra Leone, an integrated science curriculum has been implemented for primary schools through the Science Curriculum Development Centre. The evaluation activities involved the use of open-ended "teacher reaction" sheets, inventories of children's classroom activities, studies of the effectiveness of inquiry training procedures, the influence of innovative science teaching practices upon teachers' activities in non-science classes, and the ability to identify with the local environment and to be assimilated into an existing system [Francis and Dyasi, 1971:97–105].

Diversification of evaluation procedures is likely to have substantial "spin-off" value for the evaluation of progress of individual students, since the data gathered for individual students at the summative evaluation stage is also that used traditionally to evaluate the "progress" of students, and is being increasingly used as a basis for modifying teaching strategies, and for helping in making decisions about whether to adopt a curriculum for a longer term.

An example of the type of feedback obtained from summative evaluation is provided by a research study conducted by Herron [1971:203]. Fifty teachers using new secondary science curricula (P.S.S.C., B.S.C.S. and C.H.E.M. Study) were interviewed. Herron found that the teachers were committed to "science product" outcomes, despite their involvement in curricula purporting to be more process-oriented.

Meyer [1971:119] discussed the problems of summative evaluation of experimental science curricula in developing countries, and recommended simple techniques "to obtain approximate assessments of the effectiveness and suitability of new science courses". He suggested a "zero" (= ineffective) to "100" (= very high level of effectiveness") scale on each of six criteria, with the sum providing "the probability of success of the new course when transferred from trial schools to all schools". Following a review of the political, social and educational needs in several developing countries, Meyer nominated "the following criteria by which to judge the 'success of a new course'."

> "(1) Achievement of basic concepts by the pupils
> (2) The acceptance and effectiveness of the recommended teaching strategies
> (3) Achievement of objectives in typical lessons
> (4) Relevance of content to life after school
> (5) Relevance of objectives to national aims
> (6) Extent to which administrative problems of the course have been overcome:
>   (a) supply and maintenance of equipment and other resources
>   (b) extent to which equipment has been improvised
>   (c) suitability of the teachers."

[Meyer 1971:122]

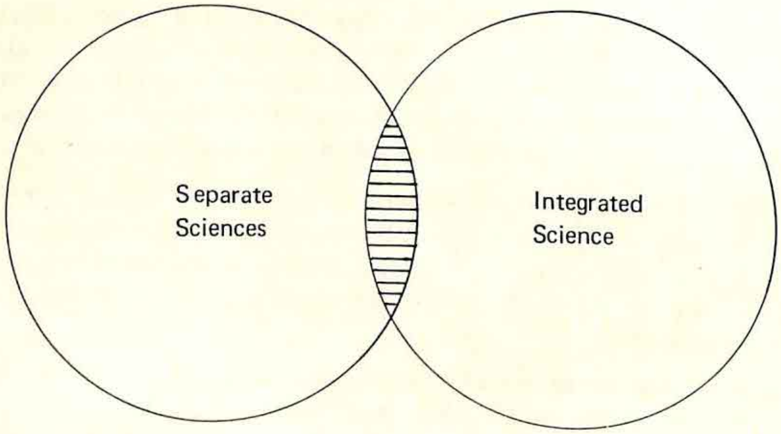
In applying summative evaluation procedures to integrated science curricula, it should be stressed that "separate sciences" and "integrated science" curricula seek to develop different educational objectives. According to Heath [1962:216], the composite question of "which curriculum, 'the old or new, is better?' . . . is inherently unanswerable." Scriven [1967:64] disagrees, stating:

> "When we come to *evaluate* the curriculum, as opposed to merely describing its performance, then we inevitably confront the question of its superiority or inferiority to the competition."

The reconciliation of these two views is proposed by Wiseman and Pidgeon [1970:89], who state that

> "occasions will arise where comparison is obviously desirable and useful, and others will occur where little extra will be gained by the additional trouble and expense involved in comparative studies."

In any case, if these two curriculum types seek to develop different sets of objectives, common evaluation instruments can only validly be applied for those objectives which are common to both curriculum types.



Much could be written about the need to develop an extended range of evaluation instruments for the common area. Much could also be written about the current spate of creative activity in this field. Space permits only a brief sampling of some of the recent developments related to science evaluation instruments.

In the cognitive domain, more innovative types of evaluation instruments include multiple-choice tests of scientific, non-technical vocabulary designed for New Guinea children [Gardner, 1971], tests of "cognitive preference" [Heath, 1963] designed to identify curriculum-related differences in cognitive style (e.g., preference for responses based upon memorization, practical applications, challenge to information given, or upon fundamental principles), and understanding in science [Cooley and Klopfer, 1961; A.S.E.P., 1972].

Notable recent developments of evaluation instruments in the affective area include one for assessing the social climate of learning [Welch, 1969:436] and several techniques being developed in the most commendable attack on problems of evaluation in an individualized curriculum as part of the Intermediate Science Curriculum Study [I.S.C.S.:1972]. These techniques relate to subjective factors designated as self-reliance, social responsibility, and written and oral communication. Instruments for evaluating "scientific attitudes" and creativity reflect the growing interest in the need for identifying and catering for the critical and divergent thinking students [e.g., Cohen, 1971: Cohen, 1972].

The Science Curriculum Improvement Study (S.C.I.S.) has published a number of innovative "evaluation supplements" for use at primary school level in science evaluation. Teachers are provided with "Class Profiles" and "Activity Checklists" on which to record evidence of student performance on scientific attitudes, on concept/process objectives, and on laboratory activities. Definitions and examples are given to teachers of behaviours associated with four scientific attitudes, namely, curiosity, inventiveness, critical thinking and persistence. Teachers are advised to record observations of the student behaviours as they arise. The concept and process objectives vary from one unit to another, and include identifying variables, constructing and interpreting histograms, discussing experiments, sorting and grouping, serial ordering, and predicting and experimenting. Two student non-verbal instruments have been developed. One technique seeks the students' "Perception of Classroom Environment". It uses student selection of the picture which depicts which of five activities (experimenting, recording, listening, discussing, reading) "happened *most* during science class on that day."

In another non-verbal technique, students also select a picture of the face (happy, neutral, sad, angry) which tells how they feel about various science activities [Bowyer *et al.*, 1972].

The evidence from the S.C.I.S. summative curriculum evaluation*, as recorded in the profiles thus facilitates decision-making concerning the effectiveness of S.C.I.S. units in the development of concepts and process skills, of scientific attitudes and of favourable attitudes towards various scientific activities, and also assists teachers in understanding student perceptions of teaching strategies.

Instruments for evaluating student performance upon "science processes" were also reported by Walbesser and Carter [1968], based upon the A.A.A.S. behaviours. Abouseif and Lee [1965] devised three science laboratory performance tests, and also found that student performance upon them was not well predicted by performance on written science tests.

Increased attention is also being paid to the analysis of curriculum materials through the use of standardized instruments [cf., Tyler and Klein, 1968; Knight and Hodges, 1969; Shepherd, 1972; Eash, 1972].

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* If a major purpose of the evaluation program is to assist in the revision of the S.C.I.S. units, the program may also be regarded as formative curriculum evaluation.

To evaluate whether a measure of "integration" has been achieved in science teaching, both product and process components need exploration. For example, if a student is confronted with a problem concerning environmental pollution, items should probe both:

(1) whether the students can *bring together bodies of knowledge* from biology, chemistry, geology and physics in order to seek a solution; *and*

(2) whether the students can *think* like a biologist, chemist, geologist and physicist in seeking a solution to the problem.

Items should require students both to use bodies of knowledge from those fields and to think like scientists in the fields.

In the application of summative evaluation techniques to integrated science curricula, there is a limited number of *research* studies reported which bear upon this area. These are generally restricted to U.S.A. Several suffer from a narrow conception of the meaning of "integrated science curricula", or from very small samples or from dubious validity of criterion instruments.

Three summative evaluation reports were based upon curricula which combined only physics and chemistry. Peterson [1945] compared the performances of students of a fused physics-chemistry curriculum with students of separate physics and chemistry curricula. He found that the students of the fused curriculum scored significantly higher on achievement than students who studied one year of traditional physics and/or one year of traditional chemistry. Heidel [1944:88] compared students of fused physics-chemistry (with consumer emphasis), with students of a traditional physics curriculum. He found that the traditional physics students remained superior in developing specific knowledge and understandings.

Lerner [1964] reported on a project to compare students of a curriculum which (broadly) integrated P.S.S.C. physics and C.B.A. and C.H.E.M. Study chemistry, with students of separate physics and chemistry curricula. Standardized achievement tests were administered in physics and chemistry. Lerner stated "that it is safe to say that the combined course does not produce any poorer results than does the traditional course on the tests used".

Writing of his integrated science curriculum, Klopfer [1966] reported that "the reactions of our students to the new course are generally favourable and our evaluations indicate that we are progressing satisfactorily in attaining most of the objectives we are aiming for."

In a later research study, Klopfer and McCann [1969:155] sought to compare the unified science curriculum with the Princeton-developed junior-high-school science curriculum "Time, Space and Matter" (T.S.M.). These science curricula share similar objectives, seeking to develop both "the processes of scientific inquiry" and insights into major scientific concepts. Students were pretested on the "Test of Understanding Science" (T.O.U.S., designed to sample understandings about science and its aims and methods, and about scientists), and also on a specially-developed Subject Matter Test (S.M.T.) of content items not specifically taught in either curriculum. "Unified science" students were superior on the S.M.T. The unified science curriculum was described as "highly effective in teaching students about scientists as people . . . and in teaching about "The Nature of Scientific Theories'," but "weak in teaching recall", which was dismissed as "not an objective of the course" [Klopfer and McCann, 1969:163].

Slesnick [1963:302] described a study based upon a Grades 9–12 unified science curriculum. He developed a multiple-choice test concerning "a rational image of the universe" (i.e., the perception, as presented in the science curriculum, obtained of "things and events, phenomena, that when assimilated are held in the mind and create for him a picture of the universe as a whole" [1963:305]. Students of subject-centred science were matched with unified science students.

Slesnick [1963:312] found that "students who have studied unified science have demonstrated a superior understanding of the unity and orderliness in nature".

Reporting subsequently upon the outcomes of the comparative evaluations of traditional and unified science curricula, Richardson and Showalter [1967] concluded that the integrated science students showed

> "greater interest in science, possessed greater scientific literacy, and performed as well in college science courses. They reported that the integrated program enhanced the achievement of many long-range goals of science instruction without sacrificing achievement or preparation for college."

Pfeiffer [1969] reported upon a comprehensive summative evaluation project of a four-year integrated concept-centred science curriculum. He used subjective techniques as well as standardized tests of intelligence and achievement. Pfeiffer's research indicated that the percentage of students electing a third year science course rose from 9% in the traditional course in 1967 to 23% after the implementation of the unified curriculum, and that 41% of all junior students had anticipated enrollment in 1971. He concluded that a totally unified curriculum is practical and is a more effective means of realizing broader educational objectives. In addition, he found that

> "Students find the unified science program to be more relevant to their needs than the traditional science program that was offered at this high school."

Based upon four research studies, Showalter [1971:103] enthusiastically claimed that:

> "Existing studies show a strongly increased interest in science on the part of high school students (of unified science courses). The usual criterion for this inference has been the significantly greater enrolment rates in elective science courses.
>
> "Additional results of certain studies show that unified science courses are advantageous when one considers the scientific literacy produced in students, the students' retention of facts and principles, and the intention of many students to major in science when entering college.
>
> "One significant finding was that there was no difference in the grades received in first-year college science courses by graduates of unified and of traditional courses in high school science. Several surveys have shown that colleges and universities consistently accept unified science course credits."

Showalter's claims about increased enrolments are also supported by Herr [1971:248] describing the introduction in 1971 of a five-year (Grades 8–12) unified high school science curriculum which evolved from an integrated P.S.S.C. physics–C.H.E.M. Study chemistry curriculum. Data provided shows that, while total upper school enrolment has increased from 118 in 1965 to 239 in 1971, enrolments in separate biology, physics and chemistry have dropped from 48 to 32, but enrolments in Phys-Chem Bio-Phys-Chem and in five-year unified science have progressively increased from 15 in 1965 to 135 [Herr 1971:250]. Such courses might be expected to arrest the swing away from science in U.K., which Keohane [1968] attributed to more able students opting out of specialized science curricula.

Showalter's claims derive support at tertiary level from Schwartz [1961:357], who expressed satisfaction with an integrated science university course "The Nature of Things", which is based upon twelve units (e.g., Cycles of Nature, Processes of Change). He claimed that the course expanded student interests in science, both by taking science majors into additional science areas, and attracting initially non-science students into scientific studies.

Another university-level course, integrating biological and physical sciences, was introduced at the State University of New York at Albany by Ward *et al.* [1969:137]. On an opinion questionnaire administered in June 1968,

> "60% of the students felt that the course had presented fundamental ideas and concepts which related large blocks of knowledge in science. The remaining 40% included students that felt the course dealt primarily with a collection of facts or even unrelated facts. Considering the normally negative attitude that many non-science majors frequently bring to such a required course, it would seem that the unified approach has at least, partially accomplished its objective. Fifty-four percent of the students' replies indicated that they felt the course had contributed to their understanding of science and how it related to society."

A different type of index of "overall effectiveness" of integrated science curricula is in terms of their adoption by teachers—providng a consensus evaluation in the form of pragmatic evidence of their attitudes in action. Table 6 examines the acceptance of courses which include more than one of the traditional separate sciences (astronomy, biology, chemistry, environmental science, geography, mathematics, meteorology and physics) [Lockhard, 1966 and 1970]. Table 6 provides evidence of a remarkable growth of development of curricula which combine two or more of the traditionally separate sciences, with the total number growing from 30 to 70 between 1966 and 1970. (See table 6)

This marked increase in the number of "combined science" curricula as indicated in Table 6 must be interpreted with caution however, since:

(1) the courses may not be fully "integrated";

(2) the increase may be due in part to increased readiness to report developing curriculum projects;

(3) the report is limited largely to widescale curriculum activity, and therefore probably ignores many integrated curricula implemented in individual schools or school districts.

Nevertheless, in terms of Beeby's educational development model [1966:58], it is not unexpected to find trends towards the teaching of integrated science greatest within the "developed" countries. In addition, of the eight projects which incorporate at least *five* sciences, all have been introduced in developed countries. It might be argued that these countries have been through the stages where teachers have been able to handle the more structured and more specialized situations of "separate sciences", and that they are now more confidently able to phase out the subject boundaries due to their experiences in the several formerly disparate studies with at least fifty of the 70 projects reported in these nations.*

In summary, summative evaluation of integrated science curricula

(1) provides evidence about the outcomes following curriculum implementation, facilitating decisions about the effectiveness and suitability of the curriculum, especially in relation to overall national educational objectives;

(2) provides evidence about the gains students make from integrated science curricula with respect to knowledge-related objectives, attitudinal objectives, and psychomotor objec-

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* These data cast doubt upon the I.C.S.U. (Bulgarian) Congress (1968) findings in which it was reported that:

"Experiments in integrated science may prove easier to carry out in developing countries. A nation with limited manpower and resources must establish appropriate educational objectives and integration of science offers many advantages towards achieving these objectives."

tives. (Specifically, are students better able to apply, analyse, synthesise and evaluate knowledge; do they hold more favourable attitudes towards science and scientists? Are students more critical, sceptical, and speculative in dealing with phenomena? Are students better able to use scientific instruments and apparatus?)

Table 6: Number of Reported Curricula Incorporating More Than One of the Separate Sciences by Nation of Implementation

Nation	1966		1970	
	Number of Curricula	Separate Sciences Incorporated	Number of Curricula	Separate Sciences Incorporated
Africa	–	–	–	(B P A C)
Australia	2	(C B Tech S,P) (C B P A G)	5	2 of (B C G P); (C B Tech S,P); 2 of (A B C G P)
Brazil	0	–	1	(B C G P)
Canada	1	(B C G P)	2	(B C P); (B C G P)
Ceylon	0	–	1	(B C P)
Columbia	–	–	1	(B C P)
Germany	–	–	2	(C P); (B C P)
Ghana	–	–	1	(B C P)
England	10	2 of (B G C P) 8 of General Sci	5	2 of (B C P Soc Sci), (B C P), (C Met P) (A B C G P)
Hungary	1	(P C)		
India	–	–	3	El. general, (B C P), (B C M P)
Israel	1	(B C P)	2	(C P), (B C P)
Japan	–	–	1	El. general
Lagos	–	–	1	(B C P)
Nepal	–	–	1	(A B C P)
Nigeria	–	–	1	"General Science"
Philippines	1	General Science	1	(C P General Science)
TPNG	–	–	1	"General Science"
Thailand	–	–	1	(B C M P)
Turkey	–	–	1	(B C G P)
West Indies (Trinidad)	–	–	1	(B C P)
U.S.A.	14	2 (P C B) 4 of Elementary Sci 2 of General Sci 2 (P C) 1 (C P B G Ast) 2 (C P B G) 1 (Ast. G O) Met)	37	5 of (C P), 1 of (As P) 1 of (B G) 2 of (C M P) 13 of (B C P), 1 of (B G P), 1 (A B C P), 5 of (B C G P), 1 (B C Geog. P) 2 "General Science" 2 of (A B C G P), 2 (B C P M Soc. Sci.), 1 (A E G Geog. O)
Totals	30		70	

Key to Table 6:
A = astronomy, B = biology, C = chemistry, G = geology, M = mathematics, Met = meteorology, O = oceanography, P = physics, Tech S = technical science.

(3) indicates whether students of integrated science curricula obtain an interrelated view of science. If so,
  (a) does this affect the students' abilities to grapple with scientific *processes*, e.g. by establishing a network of interrelationships to facilitate a different strategy in sensing and/or solving problems with underlying scientific bases? or
  (b) does it operate to sensitize the student to interrelationships of the *products* (e.g., bodies of knowledge) of the separate sciences?

(4) provides evidence about whether students of integrated science curricula are better able to seek solutions to everyday problems from an interdisciplinary frame of reference.

(5) has provided research evidence about effectiveness which tentatively suggests some advantages for "integrated science" curricula when compared to "separate science" curricula.

Major Distinctions Between Evaluation Phases

The major distinctions between reflective, formative and summative evaluation are summarized in Table 7.

Table 7: Distinctions Between Reflective, Formative and Summative Evaluation

	Reflective	Formative	Summative
Relationship to Curriculum Objectives	Assists in initial determination and refinement of overall curriculum objectives	Provides evidence of extent of fulfilment of specific (unit) objectives	Provides evidence of extent of achievement of overall curriculum objectives
Nature of Data	Knowledge about society, learners school system, "the disciplines". Value judgments	Data describing aspects of curriculum materials, and the shorter-term outcomes concerning changes of cognitive abilities, attitudes and skills	Data describing the mid-term or longer-term overall influence (survival value) of the curriculum upon cognitive abilities, attitudes, and skills
Source of Data	Jurists, including educators, discipline experts, philosophers, psychologists	Classrooms (teachers, students, administrators)	Classrooms (teachers, students, administrators). School "graduates"
Nature of Decisions	Practicability, feasibility and suitability of curriculum objectives, learning experiences, criteria selected for evaluation	Practicability, feasibility and effectiveness of curriculum units and materials, as the bases for revision and improvement	Student grading, certification, prediction of future success, teacher effectiveness; curricular comparisons
Timing	Preceding and during writing stages; before trials of curriculum units and materials	During trials of curriculum units and materials, as they are produced and while they are still fluid	Subsequent to the implementation of a number of complementary skills or concepts or alternatively, of the completed curriculum
Frequency of Administration	Before developing or revising the curriculum components	Administered whenever the writing of a curriculum unit is completed	Administered following the completion of a block of the curriculum or the total curriculum usually two or three times during a "course"
Relationship to Learning Experiences	Provides screening in terms of known constraints such as child development data, availability of facilities, teacher preparedness	Provides pragmatic evidence concerning extent of learning from curriculum units	Provides data of effectiveness of transferring the overall curriculum objectives into classroom practice

Curriculum Evaluation in Action

Confronted with the task of curriculum evaluation, where does one start? As with educational problems generally, there is no universal recipe. However, some guidelines may help to suggest possibilities.

When beginning to develop a new integrated science curriculum, try to involve a group of people at the preliminary planning stages—helping to select objectives, learning experiences and to foreshadow evaluation procedures. If any are available, involve also other science teachers, science educators, scientists of a variety of disciplines, psychologists, philosophers, sociologists, and educational researchers. Get them first to reflect upon appropriate objectives for an integrated science curriculum. These objectives may include having students experiment and observe, being involved in a blend of "process" and "product" objectives. The group may screen the objectives using such criteria as:

do the objectives reflect integrated science?

are they "worthwhile" objectives?

are they feasible for the target student group with respect to the conceptual level involved?

are they appropriate in terms of the cultural context?

do schools have, or can they obtain, needed physical facilities?

These represent only a few illustrative examples of the type of question to consider in using reflective evaluation techniques concurrently with the development of integrated science curriculum objectives.

In some circumstances, your group may involve only yourself and one or two others. Make the best of what resources are available.

When the objectives have been listed, the next task is to translate them into learning experiences. What should the learner *do,* in order to develop the specified objectives? The range of possibilities is related to the knowledge, past experiences of group members, creativity and ingenuity of group members concerning scientific processes and products, and concerning relevant classroom science activities. It is also related to the availability of resource materials.

At this stage, specifications for curriculum materials (printed and audiovisual materials included) may be devised, and prototypes prepared—by artists, photographers and technical personnel, if they are available.

Reflective evaluation as a screening device goes hand in hand with the production of these ideas and materials—just as it does in developing a grid as the basis for evaluating student progress upon the objectives, and in producing items for each of the cells of the grid.

Thus, reflective evaluation can provide a critical screen through which ideas may be progressively modified, adopted or rejected.

As the materials are developed, they may be subjected to the rigours of the classroom as a testing ground—in the formative evaluation process. Printed tests, questionnaires, informal discussions and structured interviews may be used in this process, to seek evidence of the effectiveness of the student experiences, and to explore student attitudes towards them. Pupils involved in the trials should be as representative as possible of the ultimate student target group. The availability of resources will largely determine how large this trials group can be and how ambitious the formative evaluation phase can be. If resources are limited to one person for one half day a week, largescale administration of tests and questionnaires would be impracticable, for processing the responses represents a substantial committment. In this case, weekly visits to a

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variety of classrooms for informal talks and questioning of students and teachers may represent a more useful approach. The feedback collected could assist in the progressive modification of the curriculum components during their developmental stages.

Once revised and published, the integrated science curriculum is ready for wider scale implementation, and concurrently, for summative evaluation. Data gathered before implementation is likely to be useful later as base-line data for comparisons. For example, scores on standardized science achievement tests and on other tests related to the objectives of the curriculum to be implemented, and data concerning classroom procedures and interactions may be affected following the implementation of a new curriculum.

Changes from baseline data following the implementation of a new curriculum assists in making the broad, systematic terminal appraisal which constitutes summative evaluation. Additionally, the total summary of changes in measures upon instruments representing cells in the "objectives vs topics" grid will reflect summative effects of the new curriculum.

Some Suggested Directions for Future Developments in the Evaluation of Integrated Science Curricula

The use of curriculum evaluation as a means for improving curriculum decisions has not yet been fully exploited. Reasons for this include:

> "Lack of available methodological procedures, problems of personnel expertise, insufficient tryouts of evaluation models and theories, and insufficient communication mechanisms for evaluation reports." [Weiss, 1972:244]

If the evidence for the effectiveness of integrated science curricula is to provide data to test the claims of proponents, then an improvement in the procedures for the evaluation of these curricula is demanded. What can be the hopes for the future?

An obvious strategy in forecasting the educational future is to extrapolate present trends. In this case, one might expect increasing emphases upon individualized evaluation procedures, extended diversity in types of evaluation instruments and procedures, increasingly teacher-devised evaluation, and increasing attention to different types of data available from reflective, formative and summative evaluation.

But it must be evident that much more than that is necessary. There is a need for a massive onslaught to solve the present inadequacies of evaluation of integrated science curricula. This must include:

> firstly, greater emphasis upon reflective evaluation—to reduce the problems created by ambiguities in definitions and criteria, and for screening of curriculum plans;
>
> secondly, more systematic application of formative evaluation techniques at the fluid trial stages, facilitating extensive interaction between classroom teachers and students with curriculum developers and evaluators.
>
> thirdly, a major commitment to the development and application of valid evaluation instruments in order to improve the summative evaluation stage.

Such advances are prerequisite to the evaluation of whether integrated science curricula can fulfil their promise to promote the development of both scientific processes and concepts.

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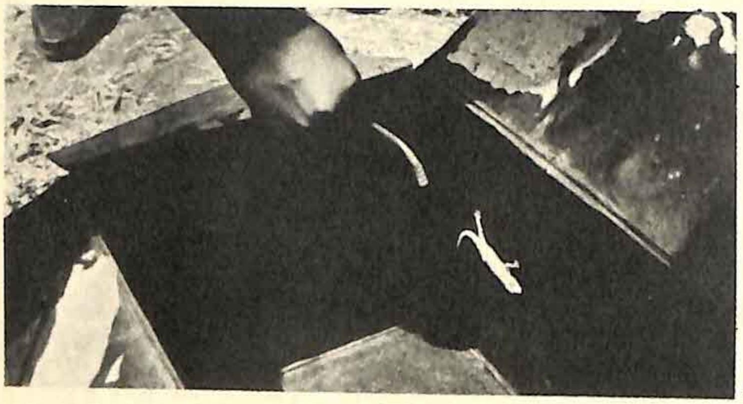

2

3

1. How long is a mouse's tail?
2. Does a Geeko like a puff of air?
3. Discussing findings.

Chapter 9

INTEGRATED SCIENCE TEACHING AS PART OF GENERAL EDUCATION–LOOKING AHEAD

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Summary

Three broad guidelines for future integrated science courses for general education are proposed centered around the concepts of *inquiry, concern,* and the ability to solve *real problems.* They are associated with the key words *curiosity, compassion,* and *competence* whose meanings are focused to represent, respectively, *the spirit of science, the spirit of brotherhood,* and *the spirit of change through design.* A tentative set of behavioral objectives for future courses in integrated science for general education is given. In an annex the relevance of these ideas to developing countries is explored.

> *"Science cannot develop unless it is pursued for the sake of pure knowledge and insight. But it will not survive unless it is used intensely and wisely for the betterment of humanity and not as an instrument of domination by one group over another. There are two powerful elements in human existence: compassion and curiosity. Curiosity without compassion is inhuman; compassion without curiosity is ineffectual."*
> Victor F. Weisskopf in an article entitled The Significance of Science, SCIENCE Vol. 176, 14 April, 1972, p. 138.

The articles that have preceded this one have dealt with many aspects of integrated science and its implementation. The purpose of this article is to look ahead and suggest three broad guidelines for the development of future programs in integrated science in general education. The key words are *curiosity, compassion,* and *competence.* Each of these words will be used in a special sense to be described as we proceed. Annex I concerning the relevance of the article to developing countries is attached.

1. *The need for new guidelines in integrated science teaching.* Great strides have been taken during the last two decades to improve the teaching of science. The first wave of reform produced projects such as PSSC, The Nuffield Physics Project, CHEM Study and CBA which stressed the *inquiry approach.* The second wave produced projects such as Project Physics (Harvard) and Earth Science Curriculum Project that were humanistically oriented and seemed to lend themselves to an *interdisciplinary* or *integrated approach.* Later, concern sparked by ecologists and environmentalists about the applications of science and technology stimulated a third wave of reform with projects such as the Human Science Program (Hurd, BSCS) and OBIS at Lawrence Hall of Science. A new concern is now beginning to take shape around the idea that it is not enough to understand Nature or to be concerned about the effects of science and technology on society. What *is* needed, we now sense, is to learn how to *do* something about them. The motives behind these trends suggest some long range goals for integrated science as part of general education based upon three main ideas: *inquiry, concern,* and *the ability to solve real problems.* From Weisskopf's article we have borrowed the words *curiosity* and *compassion* for the first two, and

we have chosen the word *competence* for the third. We assert that they are broad and valid guidelines for goals which might be implemented, at least in part, through the teaching of science in an integrated way. [1]

Since the ability to solve real problems is what we associate with competence, we should add to Weisskopf's admonition above that compassion without competence would also surely be ineffectual. Now, the ability to solve real problems is often associated with engineering and technology rather than with science, whose main concern is understanding basic principles and concepts, so it may at first seem strange to include this ability among the goals for general science. We will, nevertheless, make a plea for an extension of the domain of curiosity and concern to include not only the physical world but the world of man and society.

2. *The need for science and technology in society.* Consider broadly the main problems that beset mankind. They include accelerating overpopulation, mounting pollution of the environment and waste of natural resources, growing poverty even within economically advanced nations along with extreme deprivation in developing countries and the threat and economic drain posed by weapons of mass destruction. [2] They are interrelated and are direct or indirect consequences of the social impact of science and technology. Yet it is apparent that these problems will not be solved without further massive applications of science and new technologies. This makes it clear that we will have to educate some young people to become the scientists and technologists of the future. But they are not the only ones who need to learn some science. The nature of the world today and the trend for the world of tomorrow makes it imperative for all students of general education to learn some of the facts, methods, and concepts of science in order to play a constructive role in the world of the future. They will be the clients who can determine the uses to which science and technology may be put. Some of them will rise to be decision makers who should know something of the power and the limitations of science and technology. A case for both science and technology in general education can be built, we think, at least in part on these ideas. We should stress not only the intellectual satisfaction that comes from the explorations motivated by curiosity but also the pleasure that comes from having some "know-how" in the solution of real problems as well as the satisfaction of being guided by a sense of social responsibility.

3. *Curiosity.* This is the driving force behind scientific endeavor, and children seem to be endowed with it naturally. It is regrettable that society often forces them to cease being curious. It is also the essential ingredient in research. Here is the way Weisskopf puts it:

> "The spirit of research is composed of the following elements: an interest in understanding nature; an urge to observe, to classify, and to follow up observed phenomena for the sake of the phenomena themselves; a drive to probe deeper and deeper into a subject by experimenting with nature, by using ingenuity to study phenomena under special and unusual conditions—all in order to find connections and dependencies, causes and effects, laws and principles."

Notice how similar his criteria are to some of the ingredients of what has been called "the spirit of science" [3]:

(a) Longing to know and understand
(b) Questioning of all things
(c) Searching for data and for relations that give them meaning
(d) Demand for verification
(e) Respect for logic

These are examples of the behavior patterns we believe should be developed in all science courses but especially in an integrated course for general education. A problem for science educators of the future is to explore how teaching science in an integrated way can help infuse general education with the spirit of science. Even students who will eventually become specialists in science can, of course, also benefit from learning science in a way that motivates them to act under the guidance of the spirit of science right from the start rather than having to wait until they are graduate students doing research before becoming aware of the basic essence of the scientific approach.

Special emphasis should be given to making the learning experience pleasurable to the student. He may not experience the ecstasy which Kepler experienced when, as a result of twenty years of work, he was able to enunciate the laws under which the planets move, but surely he can have experiences and do experiments that give him a modest taste of the intellectual pleasure that comes from understanding—which is the aim of science.

4. *Compassion.* Science and technology have given man unprecedented power. Compassion can point to the proper application of this power. To use an analogy with vectors, which have both magnitude and direction, curiosity can affect the magnitude but it will take compassion to give the vector a new direction.

Perhaps one cannot teach compassion any more than one can teach curiosity, but we might devise activities to stimulate this trait in students. What place does this have in a course in science? Fifty years ago the answer was clear: none. In those days it was regarded as highly irrelevant for a professor or a teacher of science to talk about its applications. But things have changed drastically partly due to two World Wars and their sociological, economic and ethical fall-outs. The new movements, often led by students, for ecological and environmental sanity are based upon a new sense of social responsibility. [4] People are concerned about the quality of life, about the need for improvements in society and even about the survival of humanity. This implies a concern for people other than ourselves and this is the essence of compassion, not in the sense of pity, but in the sense of sympathy. Developing behavior patterns that generate compassion in children is, we assert, a valid goal for general education. [5] The question remains as to whether we can invent activities within the constraints of an integrated science course to assist in reaching this goal. Perhaps if we broaden the meaning of integration to include not only several sciences but the social sciences and the humanities as well we may find it easier to show the complementary nature of curiosity and compassion.

In order to match the five point summary of the spirit of science which we associated with curiosity, consider now a five point summary of the characteristics of what might be called "the spirit of brotherhood" associated with compassion.

(a) Affection and respect for mankind
(b) Consideration of the feelings of others
(c) Willingness to work for the improvement of society and against greed, cruelty, and oppression
(d) Acting on the inspiration of hope sustained by joy
(e) Taking premises and consequences into account before acting

The aim of compassion, as we are using the term is, then, improvement in the lot of mankind through a sense of concern and responsibility.

5. *Competence.* We are going to use this word in a very special sense which implies the capacity for design, so we will first give several examples of what we mean by design. Designing is

what an engineer does. Yet all of us, in our daily lives, have to solve real problems and tackle real projects which may be as simple as planning a holiday on a limited budget or as complicated as designing a home for a family of five.

According to the dictionary a person is competent if he possesses "know-how" or is in some sense qualified by the possession of a degree or some credentials. A plumber, for example, has a rather specialized "know-how" and a license which is his credential. But he does not, necessarily, possess the capacity for design. We must now clarify what we mean by *design.*

There was a time when the word design was associated principally with the making of drawings such as those made by ship builders and architects. That aspect of design has by no means vanished as any one can attest who has seen the vast well-lit rooms full of hundreds of draughtsmen at work in a modern aerospace plant where space craft are designed and built. But since about 1950 a new literature about design has begun to appear in which the meaning of the word has been expanded considerably. The effect of design in this broader sense is *to initiate change in man-made things.* This is the essence of the definitions of design that follow. They appear in J. Christopher Jones' book, *Design Methods.* [6]

> The imaginative jump from present facts to future possibilities [Page, 1966, 7]
>
> Bringing into being something new and useful that has not existed previously [Reswick, 1965, 8]
>
> A goal-directed problem-solving activity [Archer, 1965, 9]

In varying degrees all of us have, to some extent, initiated changes in man-made things. So we are, in some degree, all designers. That's just the point—we are all constantly called upon to design in our daily lives. Therefore, if we can learn to do it more effectively, possibly in a course on integrated science, why not do so?

Design involves us in problems and projects in which there is a wilful attempt to produce change. While it is true that in science we construct theoretical models—a design-like operation—the ultimate aim of science is to produce understanding of natural phenomena. So design is not a science. Neither is it an art nor a form of mathematics, although the approaches and techniques used in these fields are often useful in the process of design.

Here is another, narrower, definition of design, one specifically associated with engineering:

> Engineering design is the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform prespecified functions with the maximum economy and efficiency. [Fielden, 1963, 10]

The process of design is, therefore, more closely linked with engineering and technology than it is with science. Does this mean that we should really be thinking in terms of a combined course in integrated science, technology, and engineering? In spirit, yes, but in practice, since we are talking about the needs at the level of general education, we could integrate notions of design derived from technology and engineering into a special course which would still be called simply "integrated science". Adding the other terms to the title would only cause confusion.

There exist many massive unsolved problems that have been created by the use of man-made things such as traffic congestion, road accidents, airport noise, inadequate medical treatment services, and mass education. If this is the nature of problems associated with modern design, can anything significant about design be learned in general education?

An encouraging example of how concepts of design can be incorporated into elementary education comes from England where, in a small town, a group of children were confronted with the problem of what to do to help elderly people who, through illness or fatigue, became incapacitated for their normal daily tasks. The problem was to design a device that would alert other members of the community when an elderly person had become incapacitated. The children came up with the following solution. They devised a mechanism which would give a warning signal when an elderly person had not flushed the toilet during a period of 48 hours. The details don't matter here. What is relevant is that significant problems requiring design are all about us and that even children can make a contribution to their solution. Their minds are still not too encumbered by formal scientific knowledge.

Now, the earliest designers were not makers-of-drawings but makers-of-things or craftsmen. The earliest makers of boats and carriages, of bows and slings, of pitchers and cooking utensils did not work from drawings. Their designs evolved through trial and error, sometimes over generations. This suggests that some kinds of design problems could be found for children to practice their design skills after the manner of the craftsmen.

Other aspects of design that may be introduced in general education are: the concept of a system, the concept of feedback, decision making, the importance of communication and the use of media, and the need for public involvement in the design process for projects that affect society.

In summary, then, we have talked about curiosity, compassion, and competence as valid traits to be developed in pupils through an integrated science course for general education. We have associated curiosity with the spirit of science whose ultimate aim is understanding, compassion with the spirit of brotherhood which expresses itself in concern and social responsibility and, finally, with competence which we associate with the spirit of change through design. Science, and technology—the result of design—have given mankind great power for social change. Compassion is needed to give this power a direction compatible with the highest ideals of men.

Here is a tentative five point summary of "the spirit of change through design"

(a) Seeing in the imagination the things that might be and the way they are to be brought into existence;
(b) Making decisions in the face of uncertainty even when there is a high penalty for error;
(c) Judging whether something new will also be useful;
(d) Inventing models to simulate what needs to be made or done; and
(e) Using scientific principles, technology, and imagination to define new structures with prespecified functions.

The challenge for the future is to invent ways in which these modes of action as well as those associated with curiosity and compassion can be learned within the context of integrated science.

6. *Designing a course in integrated science for general education.* It is one thing to encapsulate the three spirits—of science, brotherhood and change by design—each into five succinct and possible resounding phrases which may be memorable but vague, and it is another thing to try to specify how to teach a course which performs the miracle of changing students' behavior patterns to exemplify curiosity, compassion, and competence.

To incorporate the first idea is probably not too difficult because much has been learned from the existing projects built around the discovery method and the inquiry approach. Most of the early curriculum reform and course content improvement projects were designed to infuse the spirit of science into the curriculum. To incorporate the concepts of concern and social responsibility into a course will be more difficult especially for the majority of science teachers who have been brought up to consider the goal of understanding nature as the principal one. But the widespread concern over population, ecology and environmental decay has produced some attempts at course building around socially relevant topics such as: the concept of energy and its sources in physics, the degradation of energy and the chemical nature of pollutants in chemistry, and the problems of nutrition in biology.

Very little, however, has been done to date to incorporate the idea of design into the science curriculum. It is here that we too, in the spirit of design, must *make the imaginative jump from present facts to future possibilities* and *create something new and useful that has not existed previously.*

One thing seems certain: if we are to incorporate design concepts into the course, the students must tackle *projects.* In teaching the basic sciences even without introducing the parameters of social responsibility and design, it has been found that the project approach is useful. If we want to introduce design we think it is absolutely necessary. The student must actually *generate change (hopefully improvement) in some man-made things.*

The task of creating new courses in integrated science which promote student activities based on our guidelines will have to begin by stating behavioral objectives. This will require a team effort and many man-hours of work. Nevertheless, in order to provoke discussion and stimulate action, we propose very tentatively three objectives stated in behavioral terms. A student in an integrated science course for general education must demonstrate his grasp of the three main goals as follows. He must:

(a) have planned and executed a project in which he was led, mainly out of curiosity, to explore some phenomenon in nature in order to understand it. (curiosity)

(b) have planned and executed a project motivated by a real problem involving personal or social needs of people. (compassion)

(c) have planned and executed a project in which the result was an improvement on some useful man-made thing. (competence)

A single project exemplifying one or more criteria (a, b, and c) would be acceptable.

Annex I

Comments in relation to developing countries

At the beginning of this essay, it was noted that human society is in a state of emergency; it is confronted with many problems–population, poverty, pollution, racial tension, social injustice. These issues are as much the concern of developing countries as they are of developed countries, and they demand urgent solutions. These macro-problems also have their counterparts in relation to the individual. The latter relate to uncertainty and ambiguity, resulting in intellectual and emotional insecurity. Some of these situations have been generated by the impact of science and technology applied with limited competency and restricted concern. The effective resolution of these problems demands, in large measure, the generation of populations throughout the world, developed and developing, with curiosity, competence, deep concerns and commitments. In this context, therefore, the pursuit of the wider goals of science learning, as indicated, is immediately relevant to the developing countries.

It is often thought that the learning of science and technology requires *expensive* equipment and instrumentation. While it is true that scientific enquiry entails the use of equipment, the more discriminate pursuit of the wider goals of "curiosity", "compassion", and "competence" entails more a re-orientation of values and the establishment of attitudes rather than the provision of equipment and materials—the materials in the immediate environment being rich with possibilities in generating activities linked to these goals. The whole world is a laboratory and all that is in it is "materials and equipment" for this expanded form of science learning.

In developing countries badly needed and scarce resources have been committed to science education. This has been done through a conviction that this investment is worthwhile not only in producing the needed specialists in science, but, even more critically, in producing a scientifically literate and numerate population with the relevant competences to participate in development. Even the most significant specialised findings of science and technology will fail to yield dividends unless they are examined with curiosity, accepted with understanding, and used with competence and concern. One can cite situations which illustrate this multi-dimensional nature of the demanded performance, not only in relation to simple situations concerning personal health and nutrition, but in relation to larger issues concerning entire populations. A specific case is the use—with understanding, concern and competence—of a new seed in the development of specialised varieties of rice made available to Asia through the research activities of the International Rice Research Institute. This example illustrates the critical importance of nation-wide participation in all dimensions and at all levels. It is in this type of context that valid science learning in the framework of general education can contribute most effectively to development.

In some developing countries in recent years science learning has been narrowly pursued sometimes with "an excess of faith" in its efficacy. We postulate, however, that the valuable returns can be achieved only if the wider goals which are now being recognised in science learning are pursued with genuine concern. A basic assumption underlying these assertions is that the yearning to be curious, the capacity to be competent, and the capability to function with compassion is not a function of race, creed, or color.

Rural societies in developing countries often have strong traditions which demand that individuals act with deep concern for the other members within the group. Some of the patterns of action in extended family relationships in Africa and Asia for example are instances of social correlates of these traditions. In the context of science education development the goals of science learning have, in past years, been thought to be antagonistic to the growth of such valuable traditional attitudes. Emerging insights in relation to science learning may well indicate that far from being antagonistic, the wider goals of science learning are supportive to the wholesome development of such group concerns in ways appropriate to the future. Hence, the overtones of science teaching now emerging may well find rich modes of interpretation in the rural societies of the developing world.

On the other hand, an opinion expressed by leaders in education of a developing country seeking an economic solution to its problems via industrialization, namely India, is the following: [11]

> "The greatest contribution of Europe doubtlessly is the scientific revolution. If science and ahimsa join together in a creative synthesis of belief and action, mankind will attain a new level of purposefulness, prosperity, and spiritual insight. Can India do something in adding a new dimension to the scientific achievement of the West? This poses a great challenge and also offers a unique opportunity to the men and women of India, and especially to the young people who are the makers of the future."

Pandit Jawaharlal Nehru has said:

> "Can we combine the progress of science and technology with this progress of the mind and spirit also? We cannot be untrue to science because that represents the basic fact of

life today. Still less can we be untrue to those essential principles for which India has stood in the past throughout the ages. Let us then pursue our path to industrial progress with all our strength and vigour and, at the same time, remember that material riches without toleration and compassion and wisdom may well turn to dust and ashes."

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Examples from Integrated Science Projects and Publications

These examples represent only tiny fractions of the programmes of the project or scheme. Several are drawn from trial editions and are not necessarily representative of the complete work. It is hoped however that these few examples will give some idea of the breadth of age, methods and content covered by integrated science.

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Inks and Papers

INTRODUCTION

When pupils are allowed to work freely with materials, they will sometimes come upon a discovery that interests them very much. The discovery will interest them so much that they can spend many lessons just trying to find out more about it. When talking about their discovery, they may come up with several suggestions to explain it. Just talking about it, however, will not be enough. The teacher can help his pupils test their explanations. He can help them make simple apparatus. He also can introduce other activities which the children have not thought about, but which may help them gain a better understanding of the problem they are trying to solve.

This unit, *Inks and Papers,* is based on a discovery that interests children very much:

Put a drop of ink near one end of a narrow strip of paper. Put a drop of another colour of ink on top of the first drop. Now hang the strip up. The end which the ink spot is near should be at the bottom. The water should not touch the ink spot at first. Soon the water will soak into the paper and carry some colour from the ink spot up the paper. The two different colours of ink will be carried up the paper in different amounts. The colours that were together in the ink spot will be separated.

Your pupils will be suprised at this result and may suggest explanations for how the colours were separated.

The activities in this unit are concerned with this problem. They deal with a number of suggestions that pupils have often given to explain this result. Some ways of making apparatus and some ways to use it are included to help your pupils find out whether their explanations are true or not. Some of the activities toward the end of the unit are not usually brought up by the pupils, but it is hoped that these activities will help pupils gain a better understanding of the questions they are trying to answer.

During this unit, your pupils will be learning that there are many things to think about when answering a single question such as: "Why did the colours in the ink spot separate?" They also will be learning a lot about how scientists work to try to find an answer, or answers, to a question by doing many experiments in many different ways, using a variety of materials and apparatus.

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Materials

Many of the materials mentioned in this guide can be brought from the children's homes. Such things as ink powders, blotting paper, and pins are usually supplied to the school by the County Education Officer. A box of 32 empty pint size tins may be obtained from most petrol stations for very little cost. Uniformity of tin size will help in the making of balances. The following list gives most of the materials that you will need in teaching this unit:

Ink, three colours
Blotting paper
Newspaper
Small Pieces of other kinds of paper
Bottle tops
Small thin sticks, or grass
Tins
Pins, or thorns
Liquids such as paraffin, cooking oil, spirit, tea, coffee, water
Powders such as sugar, salt, soap
BIC pens, blue and red

(The cheapest type of BIC pen has ink which works the best for the last few activities.)

Outer and inner tubes of BIC pens can be used for measuring liquids.

If the inner tube is used for measuring liquids, it should be cleaned first. This can be done by placing it in soapy water and pushing a thin reed or wire through it several times.

Background Experience
(For teacher and pupils)

When water is dropped on an ink spot on a piece of paper, the ink spreads out into a wide circle. Water dropped on to a spot which was the result of more than one ink will produce several expanding circles of different colours. A similar kind of result is obtained when ink is placed on a paper strip. If this paper strip is placed vertically in a tin of water so that the spot of inks is above the water, several colours will be found at different heights along the strip on the following day.

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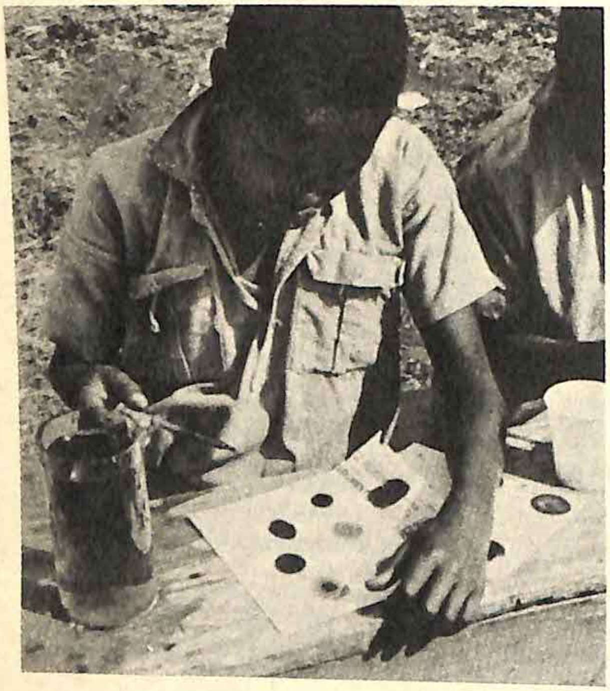

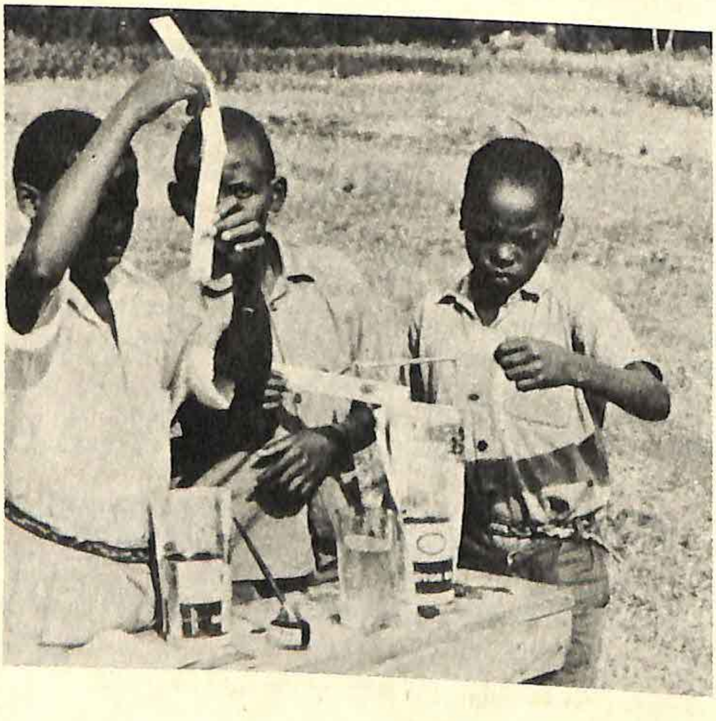

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Before doing the activities in this unit, it will be necessary for your pupils to become familiar with the results just described. If your pupils have already worked with the unit *Colours, Water and Paper* they will be familiar with these results. However, your pupils may not have done this unit and you may not want to do it before this one. In that case, your pupils can spend just a few lessons finding out what happens when inks are dropped on paper. It is especially important that they do some activities with paper strips which are left in water overnight. Specific questions and activities that you can suggest to your pupils as they are doing this can be found in the unit, *Colours, Water and Paper.*

WHY DOES ONE INK TRAVEL HIGHER UP THE PAPER THAN ANOTHER?

To start this unit, it will be useful to have your pupils discuss their past experiences with activities that involved the use of paints, liquids and papers. They may have done these activities in a previous year. They may need to refresh their memory by using the actual materials. Therefore, have available in the class blue, red, and black ink, water, plastic tubes from BIC pens, and different kinds of paper. As the children recall their experiences, they can use these materials to point out a specific thing which may be of interest to all the class.

There are a number of questions which you can ask to help guide the discussion.

Does ink or water spread at the same rate on different kinds of paper?

What happens when water is added to paints and ink spots on different kinds of paper on a flat surface?

What happens when water is placed slowly on a spot that is a mixture of two or more inks?

What happens when different liquids are dropped on the ink spots?

The day before this discussion you should prepare a paper strip holder. (See Appendix A.) Put two or three different coloured inks on the paper strips just above the liquid in the container. These inks should be regular bottle inks, not ink from a ball point pen. The following day you should have a strip with layers of colours at different heights.

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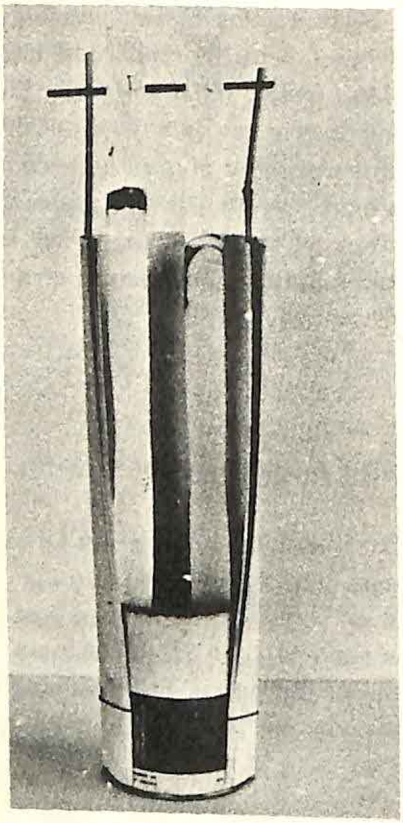

PAPER STRIP HOLDER

After the pupils have discussed all that they can recall about the ways in which ink spreads on paper on a flat surface, show them the tin with the paper strip. Let them look closely at the paper strip and discuss the results.

The pupils will usually say such things as:
"Water has gone up the paper."
"Inks have been pushed up the paper."
"Red is the highest colour."
"Black ink does not go very high."

Your pupils may start talking about the colours and how high different inks go up the same paper. This would be the natural time to ask them what could be the reason for this happening.

Usually pupils have given several reasons.
"Red ink goes faster than blue."

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"You put red ink first on the paper."
"Blue ink is heavier than red."

These are not the only factors that your pupils may suggest. They should be encouraged to consider all sorts of possibilities.

Once the children have come up with a number of suggestions, it is time to discuss them. See if your pupils can think of practical ways to test their explanations. Children often need help to think of methods and equipment to do this. Your own experience and the ideas in this book will be of help.

Before starting practical work, think about how your class should best proceed. The class may take one explanation at a time and test it in a practical way. Or you may have individuals or small groups go about testing their own explanations. In the latter case the class will be testing several different explanations at the same time.

The following are some activities that suggest ways the children can test their ideas.

I: Does the Order in Which the Inks Are Placed on the Strip Affect How High They Go?

In some classes, pupils have given the following explanation of why one ink goes higher than another. They have said that the highest ink on the paper is the one put on the paper first. That is, if red was dropped on the paper first, and blue second, the red would be the highest colour after the paper stood in the water overnight.

Your pupils may or may not give this explanation. If they do not, you can ask them to consider it. Then ask them to find some way to show whether this is true or not.

Here is one approach to this problem. First, your pupils should prepare a paper strip holder as shown in the appendix. Let them see one already made so that they can use it as an example. Then they will need to cut blotting paper or newsprint into strips that are two centimetres (one inch) wide and about 35 centimetres (14 inches) high.

Some pupils did the following with their paper strips and different kinds of inks. They dropped red ink first on the paper, then a drop of blue and finally a drop of black. Each ink was put in the same spot near one end of the paper.

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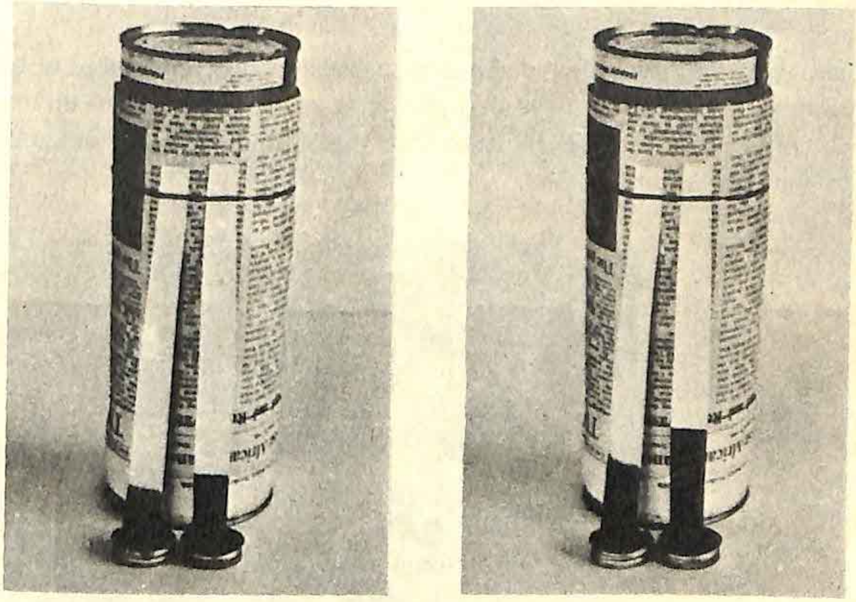
II: Do Some Inks Rise Faster Than Others?

Another explanation that children often give is that one ink is faster than another. If they found red higher on the paper than blue, they would say that red is faster than blue. Suggest to your pupils that they think about this explanation, but only suggest it if they do not mention it themselves.

Pupils can go about testing this in several ways. Here is one approach some teachers have used. They suggested that pupils in a small group have a race. Each pupil took a strip of blotting paper and put it into a bottle top full of ink. In each bottle top there was ink of a different colour.

Since bottle tops were being used, the strips were made about one centimetre (one-half inch) wide. All the pupils in a group put their papers in the ink at the same time. The ink that went the highest in the shortest amount of time was the winning ink.



When pupils have done this, they have tended to ignore certain conditions. For instance, you may find that some pupils are using blotting paper strips, while others are using newsprint strips. If your pupils try to race different inks with two different kinds of paper, they are not finding out which ink rises the fastest.

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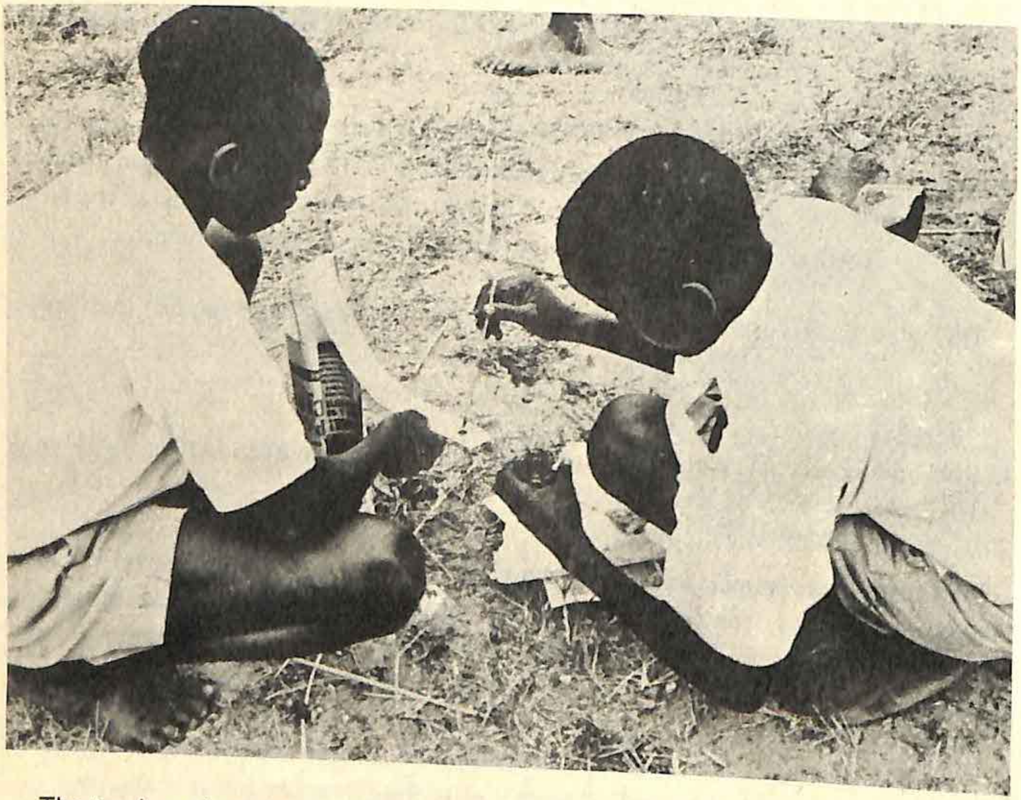
On another strip, they dropped blue, red and black ink in that order.

On a third strip, they placed black, red, and then blue.

All of these strips were placed vertically in tins of water. The spot made by the three inks was above the water line. The papers were attached with pins to the grass at the top of the paper strip holder.



The teacher asked the pupils to predict what would happen. The children said that on the first strip, red would be the highest, then blue, followed by black. In a similar way, they said blue would be first on the second strip, and the other colours would be lower.

The next day the pupils were surprised by the results. On all three strips, the highest colour was the same one. In fact, the height of each colour was the same on all the strips. The pupils were forced to conclude that the order in which inks are added does not make a difference.

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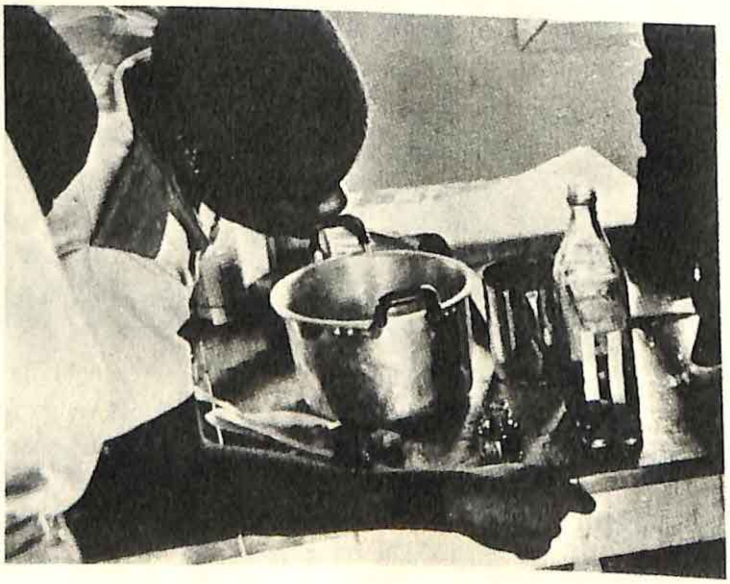
To do this, they should be using the same kind of paper. Also, the width of the strip and the amount of ink in the bottle top should be the same. The only condition or factor that should be different is the colour of the ink. It will take some reminders and some discussion before your pupils begin to understand the necessity of keeping all but one condition the same. While they are doing this activity, you can walk round the room and note whether your pupils are keeping all the factors the same.

Here is how one teacher discussed this with some of his pupils:

"Ochieng, you have a strip of blotting paper. Ogutu has a strip of newspaper. Does ink travel up each at the same rate?"
"Yes, it does."
"No, it doesn't."
"It's slower up the newsprint."
"It seems that you aren't sure. How can we find out?"
"We can put both papers in the ink at the same time and have a race."
"Are you going to have a race with the same inks or different ones?"
"The same inks."

The pupils put the two different kinds of paper into two bottle tops of blue ink at the same time. After a short while they clearly saw that the ink went up much faster on the blotting paper. The teacher then used the occasion to point out the need for keeping all the conditions the same.



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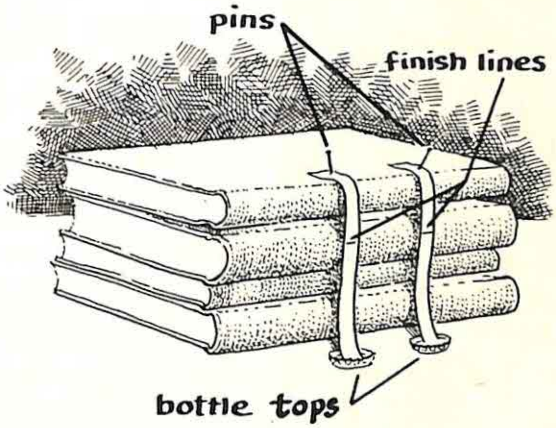
After racing the inks several times, some pupils decided to have a finish line. They drew a line several inches from the bottom of the strip. The first ink to touch this line was the winner. They also decided to attach the tops of the paper to a stack of books, so that they did not have to hold the paper for a long time.



In another class, the racing time was extended. During the lesson the pupils found that some inks do go faster than others when a race lasted only a few minutes. They wondered what would happen if the race was to last for one day. To find out, they left their papers in the bottle tops overnight. The next day they found that the inks which were highest on the previous day were still the winners of the race.

APSP

African Primary Science Program

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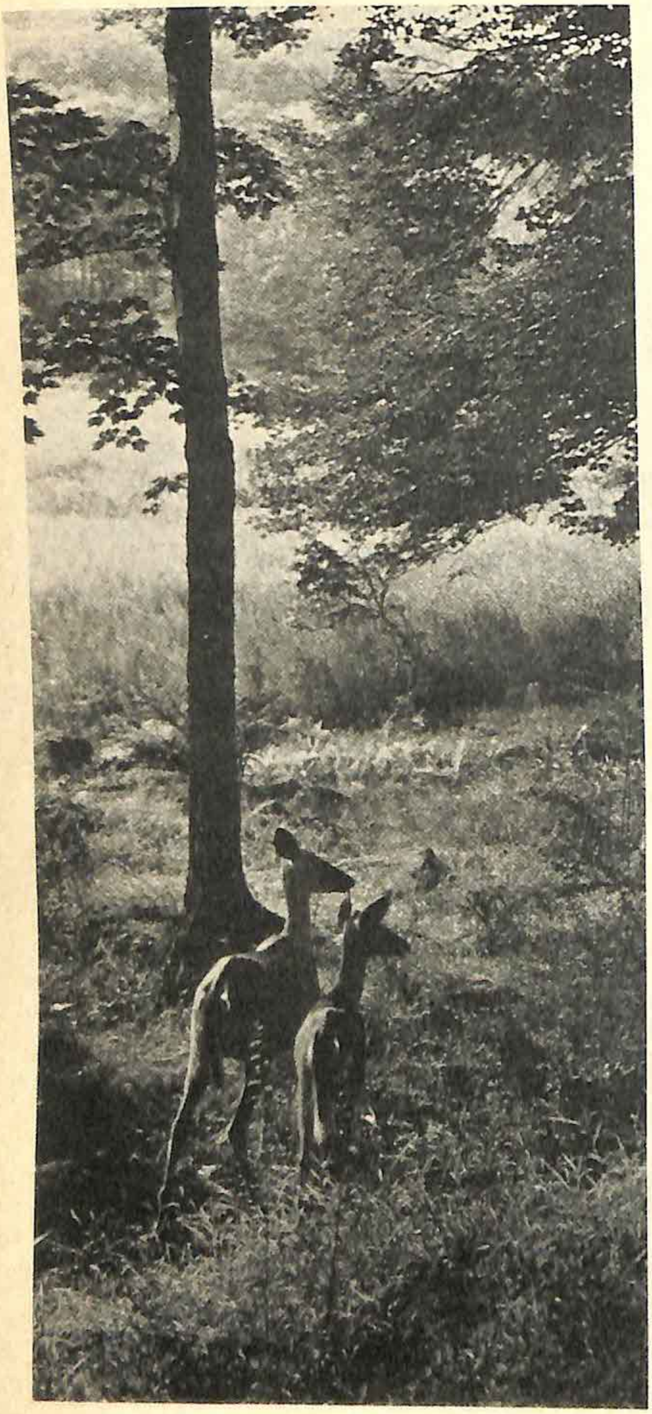

Laurence Pringle from Photo Researchers, Inc.

Environments

Part Three

Animal Responses to Environmental Factors

OBJECTIVES

To describe the range *of an environmental factor as it occurs in an experiment or outdoors.*

To determine by experiment the optimum range *of an environmental factor for an animal.*

BACKGROUND INFORMATION

Range and optimum range. The environment of any area continually fluctuates, producing varying conditions with which organisms in the area must cope. Each environmental factor can be present in differing amounts—somewhere in the *range* between its minimum and maximum—depending on the season and the time of day. No organism can withstand the entire range of intensity of most environmental factors on earth. In fact, an organism generally grows, develops, and reproduces in a small range of intensity (the *optimum range*) more efficiently than when subjected to other intensities of that factor. The optimum range of a factor for one kind of organism may be unsuitable for another.

Most animals will select a spot with favorable conditions over one where the conditions are unfavorable. They respond to changes in the intensity of a factor by moving randomly until they find an area in which

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the factors are present in optimum amounts. This kind of animal movement is often seen in deserts, where the daily temperature range can be great. For example, in the cool early morning, lizards move to rocks the sun has warmed; later in the day, they burrow deep under the sand, thus avoiding the high surface temperatures. This type of behavior enables an animal to survive in areas in which the range of intensity of certain environmental factors far exceeds its limits of survival. Therefore, our operational definition of *optimum range* is the small range of intensity of an environmental factor to which an animal moves. (This definition must be modified when dealing with plants; see Chapter 11.)

Histograms. In the physical science unit *Subsystems and Variables*, histograms are introduced as an effective technique for children to record experimental results. The children will continue using this technique in *Environments*.

One might expect organisms of the same kind to respond identically when exposed to identical conditions. In reality, some variation always exists between any two individuals. A histogram can show the extent of this variation as well as the frequency with which a particular response was observed.

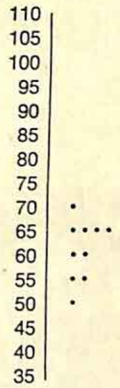
Imagine that your pupils are testing the responses of isopods to a wide temperature range. In the experiment the children determine the optimum range for isopods. Each child places his isopod in a container in which temperatures range from a minimum of 35° F at one end to a maximum of 110° F at the opposite end. After a predetermined time, say five minutes, the children record the positions of their isopods. The first ten children might report temperatures of 50°, 65°, 60°, 55°, 65°, 60°, 70°, 65°, 65°, and 55° F. These results are called *data*. To make a histogram, you construct a number line to represent the temperatures in the range. The number line may be drawn vertically or horizontally depending on available space and on which method seems to better display the data. Each child places a dot beside or above the numerical value to indicate the result he obtained. The ten results in our example are displayed on both vertical and horizontal histograms in the illustration. Both histograms show that the temperatures range from 35° to 110° F and that one isopod came to rest at 50°, two at 55°, two at 60°, four at 65°, one at 70°, and none at any other available temperature.

Using the definitions of range and optimum range, we would say the temperature *range* was 35° to 110° F and the *optimum range* for isopods was 50° to 70° F.

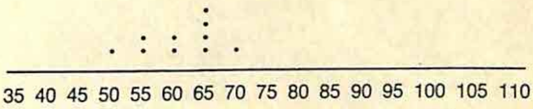
Children's experiments. The activities in Part Three contain experiments designed to help your students determine animal responses to environmental factors. They will discover that different organisms respond in diverse ways to varying intensities of environmental factors. There are two ways you may present Parts Three and Four to your pupils. You may follow the sequence presented in the guide, introducing the experiments in order, depending on the class's ingenuity to modify the experiments. The children's comments will probably consist of questions or hypotheses derived from previous investigations, terrarium observations, or outdoor experiences; and the experiments should relate to them.

You may choose instead to organize Parts Three and Four entirely

Vertical histogram.



Horizontal histogram.



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around the children's comments and questions about the success or failure of the terraria in Part One. In this case use the children's questions to determine which experiment is to be done at a particular time, rather than following the written sequence. If an experiment does not seem to interest your students, you should feel free to omit it. You could encourage the children to work individually or in small groups as they design their own experiments using the described experiments simply as guidelines and sources of ideas.

As you decide how to proceed with this unit remember that the children's experiences in forming hypotheses, designing experiments, and interpreting their data are more important than the outcome of a particular experiment.

Whichever approach you choose, you may find it easier to proceed with Chapter 6 as described, using it to introduce the range and optimum-range concepts, as well as to obtain feedback about your students' abilities to handle experimental equipment and to form hypotheses.

OVERVIEW

In Chapter 6 students investigate the response of isopods to temperature, and on the basis of their experimental results, the terms *range* and *optimum range* are introduced. Further experiments are carried out in Chapter 7, where the children determine the optimum ranges of two other factors—light and water—for isopods.

In Chapters 8 and 9 the children investigate the responses of snails and mealworm beetles to ranges of several environmental factors, and the idea of variation is introduced. In Chapter 10 the children consider chemicals as an environmental factor and determine the optimum range of salt concentration for hatching brine shrimp.

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6 "Inventing" Range and Optimum Range

The children investigate the response of isopods to many temperatures. They record their results on a class chart, and the concept of range is introduced. You use the children's data, which should indicate that the isopods moved to a smaller interval within the temperature range, to introduce the concept of optimum range.

TEACHING MATERIALS

Student-manual pages 7–8

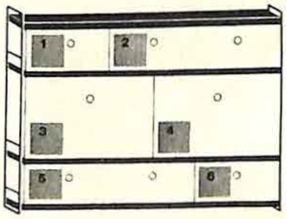
For each team of six children:

- 10 isopods
- 1 heat/light source (Drawer 2) consisting of:
  - wire frame
  - socket with cord
  - 100-watt bulb
  - brass bolt
- 1 reflector box (Drawer 2) consisting of:
  - flattened sides
  - bottom
- 3 one-pint plastic containers (one is notched—Drawer 3)
- 2 thermometers (Drawer 1)
- 7 labels (Drawer 1)
- 10 red dots (Drawer 1)
- marking pen or crayon*

For the class:

- *Isopods' Response to Temperature* chart (Drawer 1)
- 1 roll of aluminum foil (Drawer 5)
- 5 planter cups (Drawer 5)
- 5 planter lids (Drawer 5)
- ice chest (Shipment M)
- question chart (prepared in Chapter 3)
- ice*
- tape*
- scissors*

* provided by the teacher



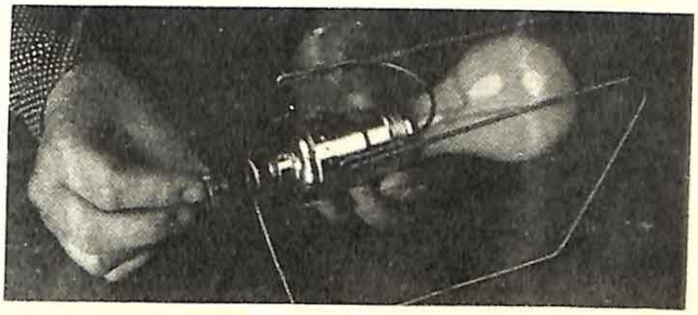
ADVANCE PREPARATION

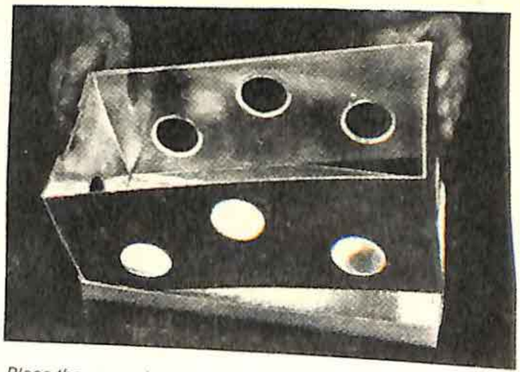
Obtain about 5 pounds of crushed or cubed ice for this experiment and store it in the ice chest. (Stored ice lasts at least six or seven hours.) Cut five pieces of aluminum foil 6 inches by 18 inches. Remove fifty isopods from the classroom container just before you need them. Put ten isopods into each of five planter cups.

To assemble a heat/light source, attach the socket to the wire frame with the bolt provided and insert a bulb. To assemble a reflector box, open the cardboard sides to form a box. Set this in the bottom. If you prefer, the children can help you with the assembly.

You will find it easier to explain the experiment to the children if you become familiar with the equipment. The instructions for setting up an

Attach the light socket to the wire frame with a brass bolt.





Place the opened cardboard sides in the bottom to form a box.

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experimental system are listed below and on page 45. The procedure is quite simple when you follow the numbered steps and illustrations.

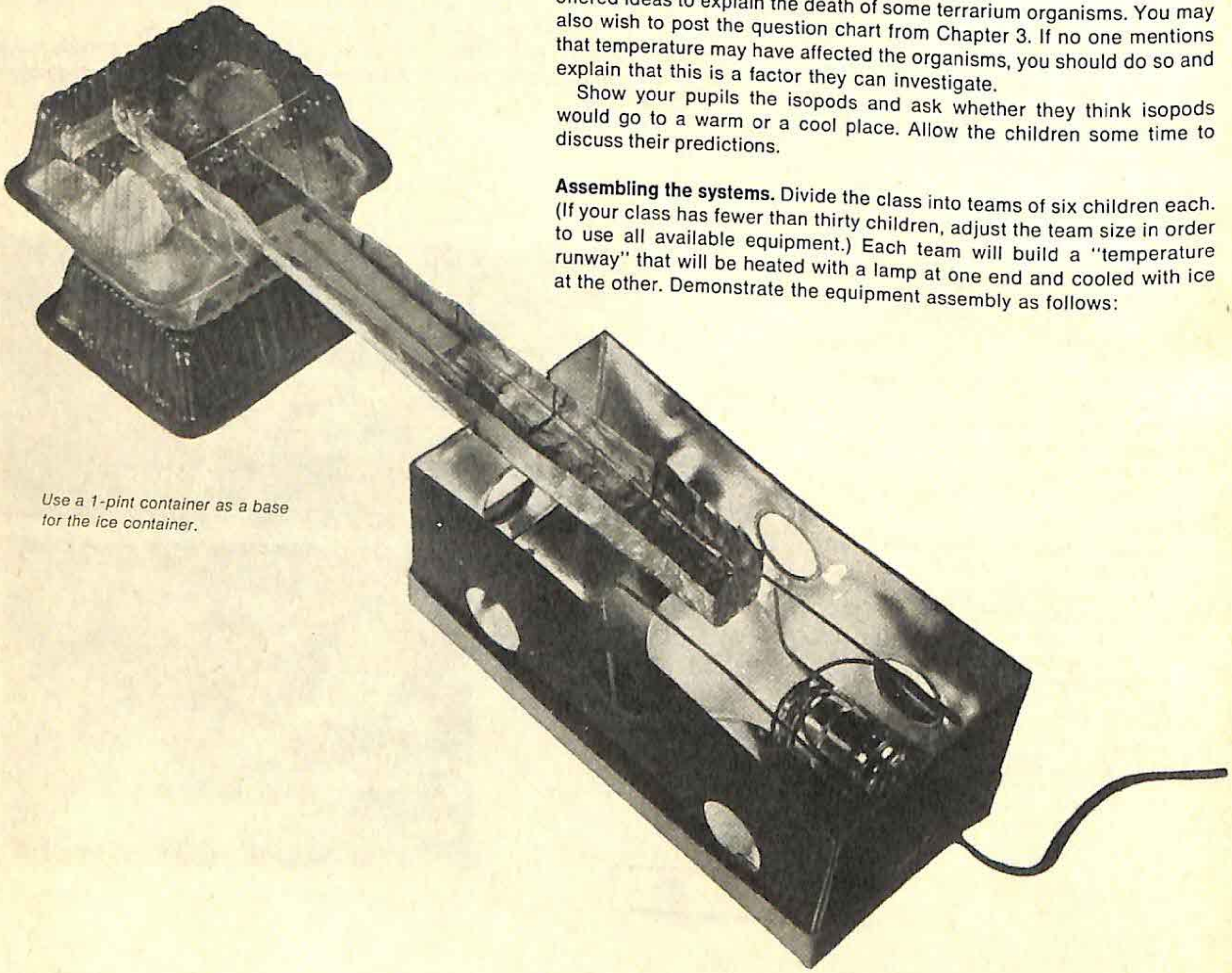
The activities in this chapter may take more than one class period. You can divide the chapter into two parts: one period to set up the equipment and carry out the experiment and a second for the chart and the inventions. A ten- to fifteen-minute waiting period is required while the runway temperatures stabilize. You may plan another activity for this period, or have the children turn on the lights and add ice to their systems just before going out to recess.

TEACHING SUGGESTIONS

Review with the children the discussion in Chapter 3 in which they offered ideas to explain the death of some terrarium organisms. You may also wish to post the question chart from Chapter 3. If no one mentions that temperature may have affected the organisms, you should do so and explain that this is a factor they can investigate.

Show your pupils the isopods and ask whether they think isopods would go to a warm or a cool place. Allow the children some time to discuss their predictions.

Assembling the systems. Divide the class into teams of six children each. (If your class has fewer than thirty children, adjust the team size in order to use all available equipment.) Each team will build a "temperature runway" that will be heated with a lamp at one end and cooled with ice at the other. Demonstrate the equipment assembly as follows:



Use a 1-pint container as a base for the ice container.

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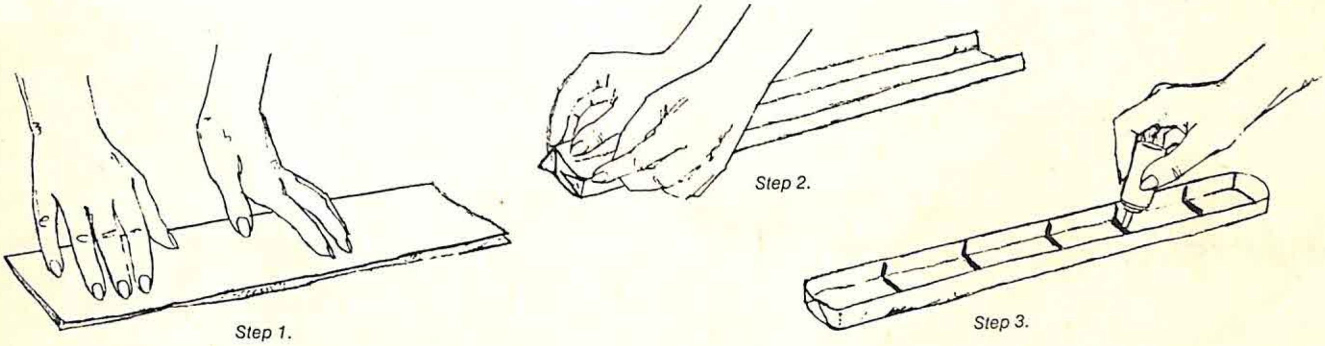


Step 1.

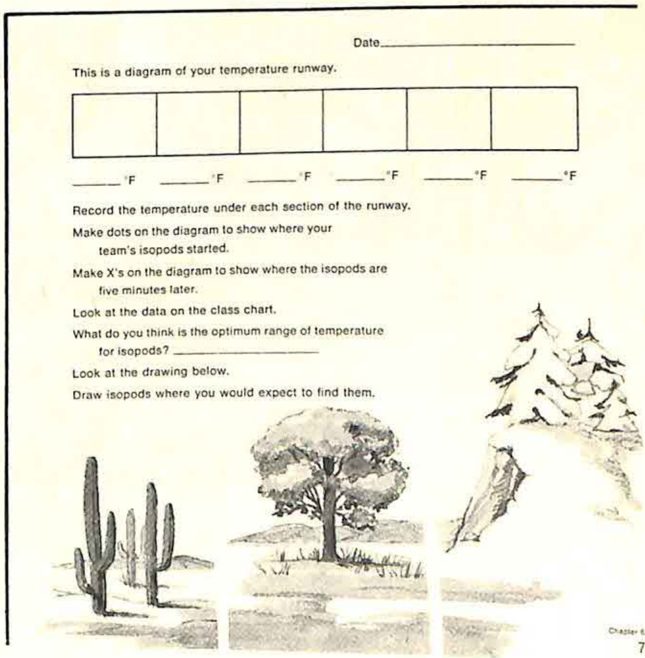
Step 2.

Step 3.

1. Fold the aluminum foil lengthwise so the resulting piece is 3 inches by 18 inches.
2. Fold up the sides and ends about ¾ inch from the edge to make a trough (use tape to secure the ends if necessary).
3. Using a marking pen or crayon, draw lines to divide the runway into six equal sections.
4. Place three 1-pint containers together on the floor as illustrated. The container with the notch should be uppermost. Use a label as a hinge to attach the lips of the top two containers to make their manipulation simpler. (The hinged container will hold ice to cool one end of the runway.)
5. Place a heat/light source in a reflector box so the base touches the end opposite the notched end of the box. Run the light cord through the hole nearest the base.
6. Place one end of the runway through the notch in the plastic container and the other end through the notch in the reflector box. The "hot" end should be directly over the bulb.

Distribute the materials to the teams. When all the teams have constructed their systems, tell them to place the ice in the hinged container, packing it fairly tightly under the end and up the sides of the runway (see illustration). After the lights are turned on, allow ten to fifteen minutes for the temperatures to stabilize.

Measuring temperature. Student-manual page 7. After ten to fifteen minutes, give each team two thermometers, and tell the children to take three readings with each thermometer. A child should place a thermometer in the center of one of the six marked sections of the runway and leave it there for two or three minutes before reading the temperature. As they measure the temperature of each section, the children should record it on a label, which they attach to the side of that runway section and on page 7. Tell them to round off the temperature readings to the nearest 5 degrees (93° should be rounded off to 95°).



Date____________________

This is a diagram of your temperature runway.

_____ °F _____ °F _____ °F _____ °F _____ °F _____ °F

Record the temperature under each section of the runway.

Make dots on the diagram to show where your team's isopods started.

Make X's on the diagram to show where the isopods are five minutes later.

Look at the data on the class chart.

What do you think is the optimum range of temperature for isopods? ____________

Look at the drawing below.

Draw isopods where you would expect to find them.

Chapter 6
7

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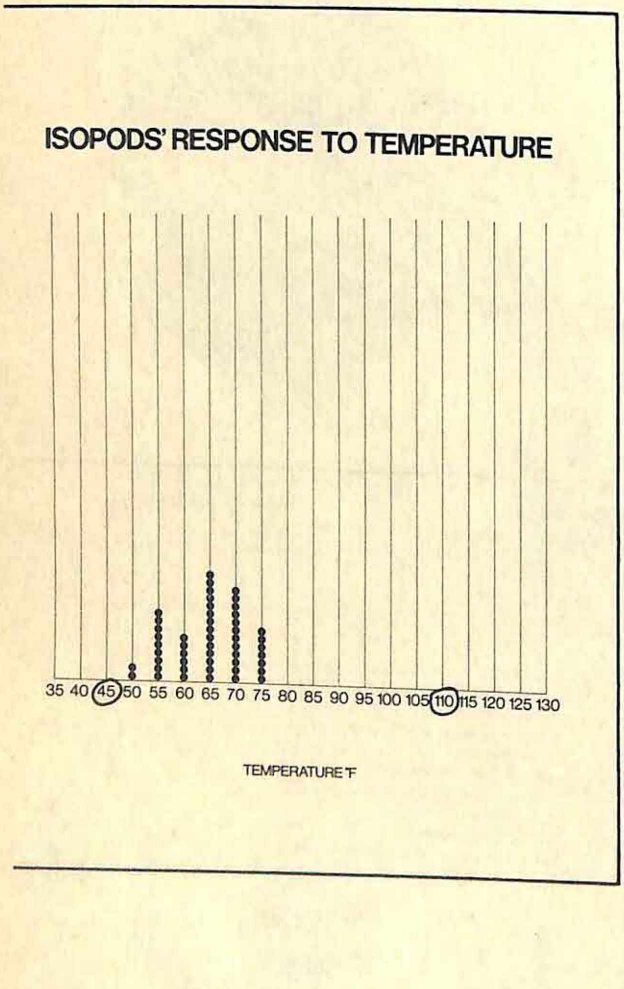
46
Chapter 6 / "Inventing" Range and Optimum Range



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Testing isopods. Distribute the cups with isopods. Each child should place at least one isopod in the center of his team's runway. After about five minutes of observation, the children should record the positions of all isopods in their runway on page 7.

Cleanup. Return the isopods to the classroom container. Collect the runways and save them for use in Chapter 7. Return the lights and the containers to the kit.

Using the chart. Display the *Isopods' Response to Temperature* chart and give each team ten dots. Using the data recorded in their manuals, tell the children to place a dot on the line that corresponds to the temperature of the runway section where each isopod was recorded at the end of the test. Dots should be placed one above the other on the appropriate vertical line. A complete chart might appear as the example on page 46.

"Inventing" range. When all the teams have recorded their data on the chart, ask one team to tell you the temperatures they recorded in the six runway sections. Ask which temperature is coldest, which is next to the coldest, and so on. Record these data on the chalkboard in a line from coldest to hottest, e.g., 45°, 60°, 75°, 85°, 95°, 110°.

Tell the children that these readings represent a *range* in the temperature from 45° F to 110° F (or whatever range is indicated). Then list on the chalkboard the temperature ranges measured by all other teams. Explain that the term *range* refers to all the intensities of an environmental factor between a minimum (lowest point) and a maximum (highest point). Then ask the children to determine the lowest and highest temperatures recorded. Using a marking pen, circle these two temperatures on the chart, explaining that these indicate the limits of the temperature range for the class experiments.

Ask the children to think of other examples of temperature range (you may wish to suggest possibilities such as the daily temperature range in the classroom or outdoors or the annual temperature range for your area). Then ask the children to suggest ranges of other environmental factors (for example, a range of light or water).

"Inventing" optimum range. Refer to the chart and ask at which temperatures most of the isopods were found (between 50° and 75° in the illustration). Are there any temperatures where just a few isopods were found? Are there temperatures where no isopods were found? Tell the children that the segment where most of the isopods were found may be called the *optimum range* for isopods. Explain that animals of a certain kind generally move to the optimum range of a factor, and ask the children what their tests indicate the optimum temperature range to be.

Note. Save the charts for use in Part Five.

Discussion. Ask the children to describe the isopods' behavior in the runways. Did they move in a certain direction, or did they wander at random? Did isopods seem to react to any particular temperature? How did they react? Did any isopods stay at either end of the runway? What happened to them? Allow the children to speculate about the advantages of animals being able to move to their optimum temperature range.

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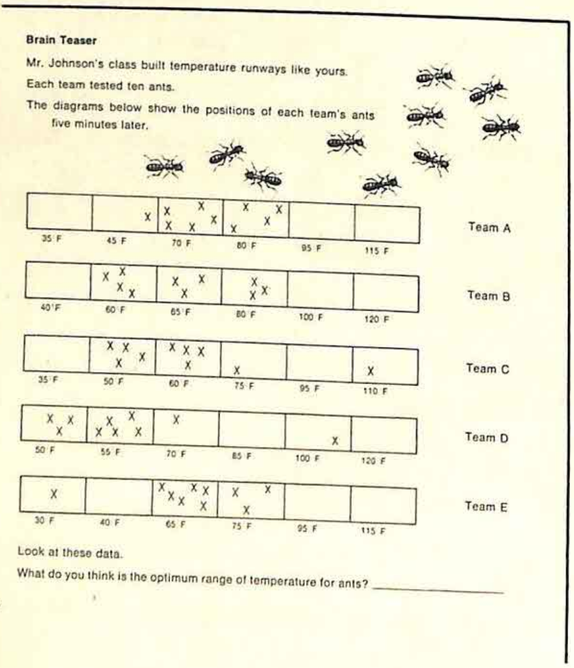
Student-manual page 8. The brain teaser on page 8 will give the children additional experience in interpreting data. You may wish to suggest that they construct histograms to combine the data. (Some pupils may need assistance in constructing a number line.)

OPTIONAL ACTIVITIES

Lowering the temperature. Some children may be curious about the effect of lower temperatures on isopod behavior. If so, give them the opportunity to modify their systems to reduce the temperature of the cold end. A piece of Dry Ice carefully placed under the runway should make that end considerably colder than in the previous experiment.

Temperature range outdoors. Your students may wish to measure the temperature range outside the classroom. They may not realize that temperatures given on newscasts or in newspapers are for only a small spot and that another area only a short distance away may be several degrees warmer or colder, depending on its exposure to the sun. Divide the class into groups to measure the temperature range in the vicinity of the school. Each group should take several temperature readings in different parts of the school yard—both in the sun and in the shade. At least three readings should be taken in a particular area: at ground level, 6 inches above ground, and 3 feet above ground.

The class may also take temperatures of specific areas: under rocks, on the fence, or in the playground, for instance. The children can make a temperature map of the school yard by using their readings. Write the temperature readings on the chalkboard and ask them what the outside temperature range was at that time. Would the range have been different at another time of day? Relate the outside temperature range to the isopod experiment. Ask the children to refer to the class chart *Isopods' Response to Temperature* and to use the data to predict where isopods might be found in the school yard at a particular time. Save the map for use in the optional activity in Chapter 7.



Brain Teaser

Mr. Johnson's class built temperature runways like yours.

Each team tested ten ants.

The diagrams below show the positions of each team's ants five minutes later.

35 F
45 F
70 F
80 F
95 F
115 F
Team A
40 F
60 F
65 F
80 F
100 F
120 F
Team B
35 F
50 F
60 F
75 F
95 F
110 F
Team C
50 F
55 F
70 F
85 F
100 F
120 F
Team D
30 F
40 F
65 F
75 F
95 F
115 F
Team E

Look at these data.

What do you think is the optimum range of temperature for ants? ____________

SCIENCE CURRICULUM IMPROVEMENT STUDY

EXTRACTS FROM THE WEST INDIAN SCIENCE CURRICULUM IMPROVEMENT PROJECT

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Unit 3: Looking at Materials

Activity 3.13 H : Industrial Processes

Level: Lower Secondary
Location: Homework

EXERCISE:

Ask different members of the class to find out what they can about

(1) How sugar is produced.
(2) How gasoline is produced.
(3) How pure water is provided for our home.

They should write at least two pages about what they find.

This homework will be taken up in Activity 3.18 where the emphasis will be mainly on the separation processes involved. In water this will involve purifying the water i.e. separating bacteria and water.

Give as much guidance as you can to books available in the school, charts and other local resources.

Activity 3.14 : Separation (a discussion lesson)

Location: Classroom
Time: 1 period

OBJECTIVES:

(1) To draw attention to the need for separation. If we want to study materials closely we must try and get them apart from all other materials. This develops the concept of purity. In this Unit so far we have been concerned with mixing substances now we turn to unmixing.
(2) This lesson is planned as a discussion lesson which will lay the foundations for practical work in 3.15 and 3.16.

EQUIPMENT:

1 Bottle of water with an insoluble substance in it e.g. calcium carbonate, copper oxide
1 Bottle muddy water
1 Filter funnel
2 Circles filter paper
1 Distillation flask fitted with cork or bung
1 Long glass tube 1 cm diameter
1 Liebig condenser (if available)

PROCEDURE:

(1) Introduce the lesson by discussing the various mixtures made in previous activites. These include

Solid and Liquid – sometimes the solid dissolved
– sometimes the solid did not dissolve

Solid and Liquid – sometimes there was a reaction
Solid and Solid – sometimes they reacted
– sometimes they did not.

The aim of the next few lessons will be to unmix mixtures; that is, to get the original materials back again. Let us see how many ideas the pupils have on the subject.

(We have not yet introduced filter funnels, separating funnels and distillation flasks so the discussion can be quite open to start with. If some pupils have met them previously accept this and work from that point.)

(2) A solid and a liquid (not a solution). Display a bottle with some solid material in water e.g. calcium carbonate powder, copper oxide and a second bottle of muddy water.

Ask for suggestions. Try to get someone to suggest a method which involves holding the solid back whilst the liquid passes through.

Introduce the filter funnel and filter paper. (Practical experience to follow in 3.15 when another method–centrifuging, may also be demonstrated).

(3) A solid and a liquid (a solution). This has already been introduced. How do you get the copper sulphate crystals back after dissolving them? Review evaporation and crystallisation.

But in this instance how could you get the water back? We have not dealt very thoroughly with condensation e.g. of water vapour so this question may give rise to some difficulty. Some pupils may have come across the technique of distillation already; if so ask them to explain to you and to the rest of the class what they mean.

An approach from first principles might follow the following line: Take a flask or a beaker with ice and water in it–preferably with a stopper or a tight cover. After a time water will start collecting on the outside and drip off. Where has this water come from? From the air, which always has some water vapour (or gas) in it. Why does the water collect (condense) on the flask? Because it is cold.

So how could we get the water back when we evaporate a solution of copper sulphate? Someone now should suggest putting a cold surface above it i.e. try to cool the water vapour.

Show the class a distillation flask. This is constructed so that the steam comes out of the side arm. (Put a stopper in the neck and do not use a thermometer at this stage). Connect the side arm to a long glass tube. The steam must pass through this and should get cold on the way–how could you increase this possibility? By keeping the tube really cold. Now show the class a condenser designed to do just that–cold water from the tap surrounds the straight tube all the time. This will be developed further in 3.15.

(4) Solid and Solid.

We want to discuss the cases where reaction has not taken place. Before they have reacted copper and sulphur are not difficult to separate. After they have reacted it becomes very difficult to get the copper and sulphur back again.

These examples should be taken as problems for discussion.

(a) Separate rice and peas (dry)–sieving or sifting.
(b) Matchsticks and stones–floating the matches off.
(c) Iron and brass nails–magnet.

(d) A candle and its wick—melt the wax.
(e) Salt and iron filings—magnet.
(f) Salt and sand—dissolve the salt, filter off the sand, recrystallise the salt.
(g) Salt and sugar—(we do not expect pupils to think of fractional crystallisation which is probably too difficult for them but see what they suggest).
(h) Copper and sulphur—sifting, or find a liquid in which sulphur dissolves.

(5) Optional. This could well be started in 3.16. We have not yet looked at the solubility of liquids in liquids and the first point to establish is that some liquids mix i.e. are soluble one in the other. Whereas others do not. Alcohol and water and kerosene and water should be taken as two contrasting examples.

Leave the separation of immiscible liquids to homework 3.17 H.

Discuss the possibility of separating two liquids which have been mixed e.g. alcohol and water. What ideas do the pupils have? By comparison with the distillation of copper sulphate solution, someone may suggest distillation but press them to think this out more thoroughly. Why should distillation separate two liquids? (The question should be asked in an encouraging tone rather than a discouraging one because the answer is on the right lines). The point we want is that if the two liquids boil at different temperatures, then one may boil over first.

The boiling points of alcohol and water are 78°C and 100°C respectively so there is a good chance that they may be separated.

This will be investigated in 3.16.

Activity 3.15 : Separating Solids and Liquids

Location: Laboratory
Time: 1 period

OBJECTIVES:

(1) The basic objective is to develop the concept of a pure substance. Separation is only a means to an end.

(2) To develop skills of filtering and distillation on a small scale.

(3) To establish a basis for a later (3.19) comparison of filtration and distillation in purifying water.

EQUIPMENT:

22	Bunsen Burners
22	Retort Stands (or funnel stands)
22	Filter funnels
25	Filter papers
22	Beakers to collect filtrate 100/400 cm^3
22	Beakers of muddy water approx. 50 cm^3
1	Centrifuge (if available)
1	Liebig condenser with tubing
22	Distillation apparatus—test tube 125 × 16 mm either with side arm or with cork and right angle tube short rubber tubing and 20 cm straight glass tubing.
22	Test tubes 125 × 16 mm to collect distillate
	Various solutions of coloured salts, 250 cm^3 in all
	Distillation flask with thermometer
1	Tripod and gauze

PROCEDURE:

This Activity follows on from 3.14 where the procedures for separating substances were discussed. This means that work can be started quickly.

(1) Separating solids and liquids—filtration. Demonstrate the folding of filter paper, placing it in the funnel and running in a little water to moisten and hold it in place. Set up two on your demonstration bench. Pour water with calcium carbonate powder in it into one and potassium permanganate or copper sulphate solution into the other, showing that the water level should be 1 cm below the top of the paper. (Otherwise some material could run down outside the paper).

Observe the first coming through clear, the second is still coloured because the solid is dissolved in the water.

Distribute filter papers and supervise their folding. Pupils should now filter muddy water to see how clear they can get it after filtration. If the first filtration is not entirely successful the water may be passed through a second time.

(2) Optional. If a centrifuge is available it is worth demonstrating its operation, since centrifuge separation comes in later in the discussion of the sugar industry.

Use a freshly precipitated salt such as lead iodide (mix potassium iodide and lead nitrate solution as in 3.12 No. 11).

Repeat the demonstration with muddy water. Discuss how the centrifuging process works.

(3) Recovering the components of a solution. Since recrystallisation has already been covered practically the emphasis here should be on recovering the water. The principle has already been discussed in 3.14.

Provide pupils with a distillation apparatus consisting of a test tube with side arm or a normal test tube fitted with a one hole cork or bung, and a bent glass tube through the cork. A short length of rubber tubing and a straight length of glass tubing to act as a condenser will be required and a second test tube to receive the distillate.

The tube should be held in a retort stand so that it may be heated gently. Emphasize the gentle heating otherwise the solution itself will splash over into the condenser.

Provide the pupils with various solutions of salts, preferably coloured e.g. potassium permanganate, potassium dichromate, copper sulphate. Do not fill the tubes more than one third full. Add a small piece of porous pottery to each tube, this helps to prevent bumping. Allow the pupils to heat the tubes gently. You will be able to pick out those who heat too strongly by the colour of the distillate. Do not allow pupils to heat the solution to dryness.

If this works quickly let the pupils wash out their tubes, and try to get clean water from muddy water in the same way.

(4) Optional. Using a proper distilling flask and condenser demonstrate the distillation of potassium permanganate and the production of clean water. Emphasise the function of the condenser once more. Have a thermometer in place for this demonstration and show that its bulb should be at the same level as the side arm. Record the temperature shown during distillation—near 100°C.

Activity 3.16 : Separating Liquids

Location: Laboratory
Time: 30 minutes

OBJECTIVES:

(1) To pursue the practical study of separation.

(2) To demonstrate another technique which may be related to industrial practice.

EQUIPMENT:

As 3.15 except for filter funnels. 30 cm³ Methylated spirit.

PROCEDURE:

(1) Distilling a mixture of liquids was suggested in 3.16. With alcohol and water (boiling points 78° and 100° respectively) we expected the alcohol to boil over first. This may be taken as a class experiment or a demonstration or both.

The class could use their small distillation apparatus but the receiving tube should be cooled in a beaker of water.

Make up a mixture of 20 cm³ methylated spirit and 80 cm³ water. Take a few drops of this in an evaporating basin and see if it will burn. (It should not, and so we have a test which will differentiate the product of distillation from the original mixture). Give pupils a little of the mixture in their tubes with some porous pot (about quarter full). Let them heat very gently until a few drops of distillate have been collected. Smell this and see whether it will burn. If so the first material distilling over contains more alcohol than the original mixture.

Demonstration. Carry out the demonstration in a distillation flask with a thermometer. Ensure a good flow of water through the condenser and cool the receiver in water. Read the temperature when the first distillate starts coming over and again test a few drops for burning. Continue reading the temperature until about one half of the mixture has distilled over. In this time change the receiver four times. Finally compare the smell of the four tubes of distillate and their burning properties. For burning take a few drops in an evaporating basin each time.

Activity 3.17 H : Separating Liquids, Designing a Separator

Location: Homework

EXERCISE:

This is an exercise in devising a piece of equipment for a particular purpose. It is based on the assumption that pupils have not yet encountered a separating funnel.

> "As you know kerosene and water do not mix. Can you devise a piece of equipment which would be used to separate the two?"

MARKING:

Try to find out whether any of the pupils have been looking at books for their ideas. There is nothing wrong in this but original ideas should be equally rewarded even if they do not come up with the accepted product.

NOTE:

This could be a short homework but the previous homework 3.13 H may still not be complete and pupils may need further guidance and time.

Activity 3.18 : Separations in Industry

Location: Classroom
Time: 1 period

OBJECTIVES:

(1) To relate laboratory experiences to important industrial processes.

EQUIPMENT:

As many charts and as much literature on the various processes as you can gather.

PROCEDURE:

Discuss the various industries in turn letting the pupils tell you what stages the raw material passes through. Let the rest of the class pick out the various processes of separation involved. Note the following points:

Sugar

(a) Separation of juice and bagasse—a form of filtration.
(b) Evaporation and crystallisation, involving separation of molasses and crystals by centrifugal separators.
(c) Removal of colour from the sugar for the various grades.

Petroleum

(a) Petroleum (or crude oil) is a mixture of many substances, the boiling points of which cover a wide range of temperatures.
(b) The use of fractionating columns to separate liquids of similar boiling points. The relationship of a fractionating tower to the laboratory distillation flask.
(c) The wide range of products and their uses.

Water

(a) The removal of solid matter in filter beds of stone gravel etc.
(b) The removal of harmful bacteria by the addition of chlorine.

Other Industries which might be noted as examples of separation:

Spirit Distillation
Salt Industry (Seawater process)
Pitch refining
Bauxite refining

RECORDING:

A short paragraph on each industry in addition to homework 3.13 H. We do not expect pupils to remember details of industrial processes but we expect them to be aware of the different types of separation involved.

FOLLOW UP:

A visit to a factory, a refinery or a water treatment plant should be carefully thought out. An oil refinery tends to be a mass of pipes and the oil itself is not seen at any part of the process; this is probably too abstract for first formers unless there are strong local or family connections.

LET'S GROW PLANTS

An edited version of extracts from "Agriculture as Environmental Science", a curriculum project for grades 7–9. Reproduced by kind permission of the Ministry of Education and Culture, Israel.

How Does the Plant Bud at its Proper Season?

Introduction

Before planning an experiment a student should determine exactly what he wants to examine, that is, he has to define as exactly as possible the objectives of the experiment. Then he will have to decide what are the treatments required for answering the central question: "Does a certain climatic factor affect the flowering data of a certain plant?" Another preliminary problem to be solved is the correct sampling and students must also realize that the experiment has to be conducted with several replications.

After studying the text, students are asked to answer a series of questions at home. A discussion is then initiated in class, and various answers are compared with each other. More often than not there will be more than one correct answer! The teacher can be assisted by the Teachers' Guide, in which both questions and answers are given for convenience.

The planning of the experiments will be supported by a discussion in class, and though the teacher is equipped with detailed proposals for the organization of the plot, he will make allowance for logical suggestions made by his students. In the Teachers' Guide he will find an explanation why he should propose to conduct the experiment relating to effects of day length and temperature, for instance, by cooling and by illuminating in the fall. The Teachers' Guide provides a detailed rationale for choosing as experimental plants—the Chrysanthemum (a short-day plant), Wheat (a long-day plant), the Iris (a plant sensitive to thermoperiodism), Gladiolus (a bulb requiring break of dormancy only) and Sweet Pea or another plant, which is not affected by thermoperiodism or photoperiodism. However, the teacher is warned not to "reveal" these facts to his students before they themselves find them out by observations and by following the growth of the plants.

The teacher is provided with detailed technical instructions, which tell him how to organize the experimental plot, how to cool plants and how to illuminate them at night. The experience of the past five years indicates that this part of the experiment, which seems to be highly complicated, is the most exciting and the easiest to do, provided that the equipment is made available to schools in due time.

For several months students will follow the development of plants. Usually, a group of 3 or 4 students takes care of an illumination, a cooling and a control plot of a certain plant. They record data in a copybook and summarize data obtained from other students in the class. At the same time instruction continues according to the order of chapters, and more experiments are done. It is not always easy for a student to follow a field experiment patiently for a long time; but this is an essential factor in his learning, since "true" research also requires much patience. Sometimes, in field experiments, one gets unexpected results. These are quite often more interesting, providing that the teacher and students know how to analyse and how to interpret them. The personal involvement of the students in their plots usually stimulates them to complete the task they have assumed.

Various practical problems might arise while handling the plants, and students should be accustomed to refer to professional literature for solutions. To facilitate the utilization of the literature on flower growing available to the amateur flower grower, several example chapters are included in the students' text.

At the end of flowering in the various plots, the students analyse the results obtained. Results indicate that it is possible to alter the flowering date of plants. But is the farmer interested in doing so? A paragraph which explains the economic problems of the farmer follows, and leads the student to an affirmative answer to this question. The student now learns more about the regulation of flowering in Chrysanthemums and in Iris (two plants which he has already handled), and finds out that the method he employed for altering the flowering date is applicable, and capable of further improvements. Other methods for the regulation of flowering are introduced to the student, and the highlight of the chapter comes at its completion with a visit to a nursery in which the changing of flowering time is employed on a commercial scale. One of the spontaneous reactions of students in experimental classes was: "Look, he (the nurseryman) is doing exactly what we did". Others said "We have still to learn much in order to obtain such beautiful flowers". In quite a number of cases teachers reported that their students decided to try and change the flowering date of Chrysanthemums at home, which seems to indicate that they were much involved.

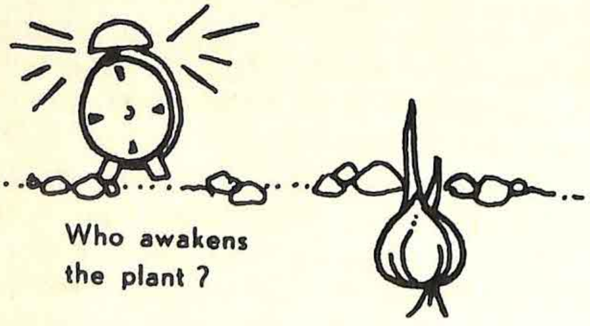
From the Students' Text

How does the plant bud at its proper season?

Have you seen a cyclamen flowering in summer? or an Urginea in spring? or an almond tree in autumn? What will happen to a plant if it awakens "by mistake" in the wrong season, for example, a desert plant that begins to bud in the middle of the summer?

Every plant has its own seasons for growth and flowering. The "clock of the seasons" is a problem which has troubled many scientists. The plant has no alarm clock which will ring and wake it up. How therefore, does the plant bud in its proper season?

If we could find out how the "clock of the seasons" works, we might be able to plan an "alarm", with which we could regulate the seasons of growth and flowering of various plants as we wish.



However, before we discuss this possibility, we shall have to discover which factors are likely to affect the awakening of plants and their flower initiation.

In the previous chapter we saw that the following factors change in nature from one season to the next:

(a) moisture (b) temperature (c) day length

The climatic factors which change from one season to the next.

The climatic factors which change from one season to the next.

Which of these factors awakens the plant? Do all plants awaken as a result of the effects of the same factor? The fact that certain plants grow and develop only in summer, whereas others only do so in spring, shows that different plants are affected differently by the same climatic factors.

The Effect of Moisture on the Awakening of Plants

Let us first think of those plants which awaken immediately after the first rain: many grasses, and cereals, both wild and cultivated, emerge after the first rain. These plants only await moisture. If we were to irrigate the fields in summer, the grass seeds would also germinate, even though this is not their season of growth.

A CULTIVATED PLANT – A plant which has been bred and grown by man.

A WILD PLANT – A plant which has not been bred and grown by man.

However, in the same field there are seeds and bulbs of many plant species which do not awaken after the first rain. How can we explain their behaviour?

How does the Urginea Awaken?

This plant is quite unlike the cereal plants. It produces its inflorescence *before* the rains come. The flowers suddenly begin to appear in the autumn in a field in which nothing was to be seen previously. How did this happen? No rain, which could have awakened it, has yet moistened the earth!

Is it possible that the change in day length awakened the Urginea plant? Let us think for a minute: Could the bulb hidden deep in the earth, notice the change in the day length? It seems very unlikely. The bulb can only react to changes in climatic factors which occur not only on, but also below the soil surface, such as temperature changes, for example.

Let us Conduct an Experiment:

Which Factors Affect a Certain Plant?

We have discussed so far three climatic factors. If we want to know which of them affects the awakening of a certain plant and determines its flowering time, we can of course try to find the answer in the *professional literature:* we shall search in books and in journals dedicated to research on plant growing. It is quite possible that there we shall find the solution to the problem which is troubling us.

However, we cannot always find an article which will give the answer to our specific question, because many problems have not yet been studied; and of the many research projects conducted, not all findings are relevant to our growing conditions. It would therefore be best if we ourselves were to try to examine the problem, and conduct our own experiment, like the scientists do.

Defining the Problem

An experiment demands both work and time; the experiment must be planned, the tools and materials have to be prepared, the experiment must be carried out accurately and every particular has to be observed and recorded so that finally the results can be summed up. We therefore have to ask ourselves before each experiment:

WHAT EXACTLY DO WE WISH TO EXAMINE?

The heading of this chapter, for example, is not sufficently detailed. We cannot expect to examine in one experiment the effects of *all* the factors (not even of all the climatic factors alone) on the plant. We cannot study a large number of factors at one and the same time. If we wished to do so, the experiment would become very complicated and also very expensive.

If, for example, the aim of our experiment was to study the effects of *all* the climatic factors, on *all* plants, how many factors would we have to examine?

Why can't we study the effects of the same climatic factors on all the phases of growth and flowering? What are the difficulties?

A Sample Homework Question

1.25 in this chapter, we have described an experiment in which the plants that were sprayed to protect them from disease bore healthy leaves, whereas the plants in the control plot suffered from a leaf disease. What conclusion would you draw if the leaves in *both* plots remained healthy?

A student said about this experiment: "It's a pity that both plots were not sprayed. If they were, the disease would not have appeared in the second plot too."

What do you think about this student's idea? In your opinion, which of the following statements is the *best* answer to this student?

(a) The student was right, because we want all our plants to be healthy.
(b) The student was right, because the disease might be contagious.
(c) The student was mistaken, because it was not necessary to spray both plots.
(d) The student was mistaken, because the unsprayed plot served as a control.

Can we Regulate the Time of Flowering?

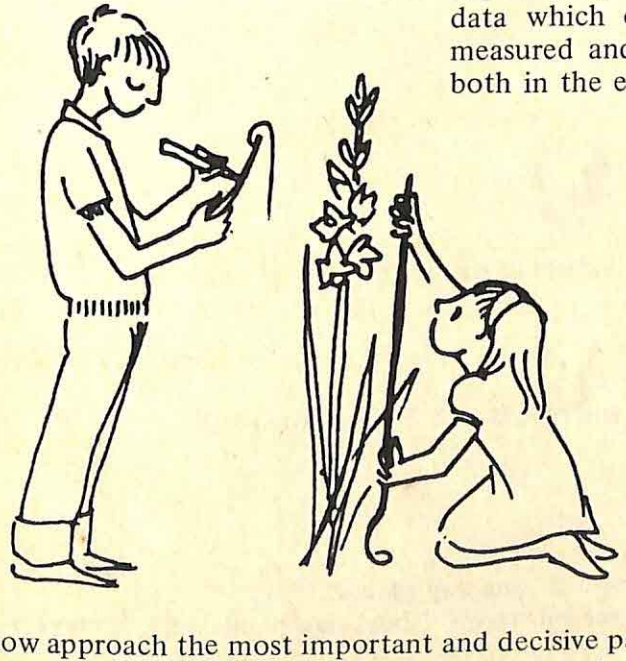
Analysis of Experimental Results

You have been cultivating your garden and following the development of the plants for a few months already. Let us now remember that at the beginning of the year we asked ourselves the following questions:

- Which factor in nature affects the flowering time of plants?
- Are all plants affected by the same factor?
- Is it possible to change the flowering time by artificial means?

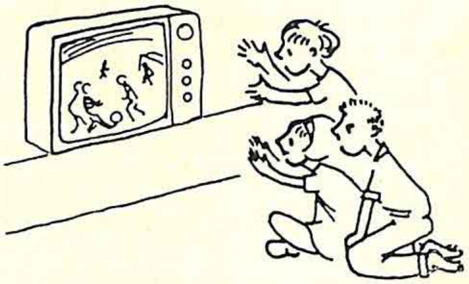
We have now arrived at the flowering time of the plants which we have grown, and we can *summarize* the results of our experiment. You can do this as you have followed the growth of the plants, written down your findings and summed them up.

The *findings* are the basis for the summing up of this experiment, or for any experiment. They are the basic data which cannot be doubted, for it was *you* who measured and counted, and you checked your findings both in the experimental plots and in the control plots.



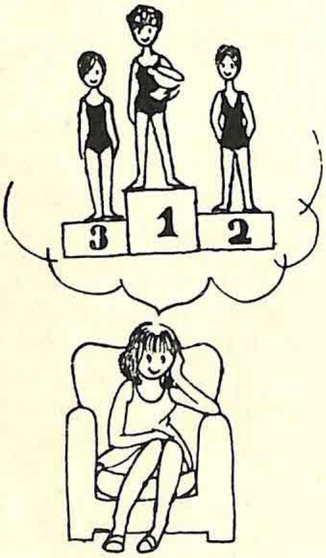
We now approach the most important and decisive part of each experiment and in all research—we must *draw our conclusions.* This is not easy and one must be very careful. It can sometimes happen that two people will arrive at two entirely different conclusions from the very same results, about which there is no agreement.

This is generally a sign that one of them drew his conclusion erroneously. For example: A few friends from the class sat in front of the television set and watched a football game in which the Israeli team beat the world champions 5 to 0! The joy was great. Three pupils began to discuss the game, Uri exclaimed: "In this case we were stronger than the world champions!" Baruch said: "We will therefore also win in the coming Olympic games". And Gilah, who was sitting near the boys and wanted to take part in the discussion shouted: "We'll also beat them all in the swimming contests."



Who, of all the pupils, drew the correct conclusion from the known fact?

What was this *fact* and how was it measured?



Who only suggested a *hypothesis* (though based on fact) and who drew an unfounded *conclusion?*

Let us now return to our own experiment. We will check and analyse our results so that we arrive at the correct conclusions. We must be most careful, as our conclusions must be based only on the facts.

Questions

(1) How did the various treatments affect the plants which we studied with regard to:
   1. Time of flowering.
   2. Length of the stem.
   3. Number of leaves.

(2) Which plants are short-day plants and which long-day plants. Why? (If you are not yet sure you understand the terms "short-day plant" and "long-day plant", look up chapter 1 page 24).

(3) Did you find any other differences between the treated plants and the control plants?

(4) What conclusion can you draw from this experiment?

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Further, if the stimulus and response are naturally related, as when you have to push the upper button on a lift to go up and a lower button to go down, then again there may not be much more time taken to choose from a larger array of choices. Incidentally, this idea of the 'naturalness' of a response to a signal is important and it is called *compatibility*. A highly compatible response is one where a majority of people in a given population accept that the response required is a 'natural' one. Note that this can differ for different cultures—in Great Britain we expect lights to go on when we push a light switch down, in North America they expect the opposite. Another example is the difficulty often experienced in steering a boat with a tiller after being used to cars. The tiller has to be pushed the opposite way to that in which you want to go, compared with a car where turning a steering wheel clockwise to go to the right is a 'natural' connection, i.e. highly compatible, but with some radio sets, for example, the tuning knob works the opposite way.

compatibility

The way the brain makes decisions of this kind is still not completely understood and there is a great deal of research going on into these topics. Current thinking is that the brain assembles evidence or information and makes a decision on probabilities or likelihoods of outside events having in fact occurred. This can be shown by looking at other factors which affect the situation, for example the frequency of occurrence of the different choices, the ease or difficulty of discriminating among the choices and, of course, practice. In our card-sorting experiment the different choices did not occur with equal frequency (there are more number cards than court cards) and it is clearly harder to distinguish between say a king and a queen than, say, an ace and a ten.

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APPENDIX

A Listing of Science Curriculum Projects of an Integrated Nature.

Prepared by Dr. J. David Lockard, Director of the International Clearinghouse on Science and Mathematics Curriculum Developments, University of Maryland.

Selected from the Eighth Report of the International Clearinghouse on Science and Mathematics Curricular Developments, 1972. Science Teaching Center, University of Maryland, College Park, Maryland, 20 742, U.S.A.

AFRICAN AREA

1. AFRICAN PRIMARY SCIENCE PROGRAM (APSP).
   Project Directors: Ralph H. Robins and Robert W. Carlisle, African Primary Science Program, Education Development Center, 55 Chapel Street, Newton, Massachusetts 02160, U.S.A.

   Primary school science; K through grade 8 only.

2. GHANA ASSOCIATION OF SCIENCE TEACHER'S PROJECT FOR SCIENCE INTEGRATION (GAST: PSI).
   Project Director: S. M. Adu-Ampoma, Principal Education Officer in charge of Science and In-service Training, Ministry of Education, P.O. Box M-188, Accra, Ghana.

   Primary and training college group. Science, PI-P8 (6-14 years), TI-T4 (16-20 years). All abilities. Secondary school group 51-55 (12-17 years). Above average ability.

3. LESOTHO SCIENCE CURRICULUM DEVELOPMENT PROGRAMME (L.S.C.D.P.).
   Project Director: Mr. E. Selai Mohapi, Director, Science and Research Division, Ministry of Education, Maseru, Lesotho.

   Adapting the West Indian Science Curriculum Programme (WISCIP) to the Junior Secondary Schools.

4. NIGERIAN INTEGRATED SCIENCE PROJECT (NISP).
   Project Director: Akin Osiyale, Lecturer in Science Education, University of Lagos, College of Education, Lagos, Nigeria.

   Integrated Science (elements of physics, chemistry and biology); 10-14 years of age.

5. SCIENCE EDUCATION PROGRAMME FOR AFRICA (SEPA).
   Project Director: Dr. Hubert M. Dyasi, Executive Secretary, SEPA, Box M.188, Accra, Ghana.

   Science for primary schools presently, ultimately science education all levels.

6. UNESCO/UNICEF, INSTITUTE OF EDUCATION CURRICULUM DEVELOPMENT PROJECT FOR SIX NORTHERN STATES OF NIGERIA.
   Contact: Paul D. Merrick, Visiting Professor of Science Education, Institute of Education, Ahmadu Bello University, Zaria, Nigeria.

   Primary science materials based upon a modified process approach.

7. UNESCO/UNICEF PRIMARY SCIENCE PROGRAM.
   Project Directors: Prof. Paul D. Merrick and Mr. Beverley Young.
   Project Headquarters: 1. Contact: UNESCO/UNICEF Primary Science Program, Ahmadu Bello University, Institute of Education, Zaria, Nigeria (INSTEDUCATE).
   Science; Primary One through Six; all children.

ASIAN AREA

8. DESKARTES.
Project Director: Dr. Shigehiro Kobayashi, Professor of Physics, Kagawa University, Takamatsu, Shikoku, 760, Japan.

Natural science; 7th, 8th, 9th grades; average students use group-paced equipment, while the gifted and the slow learners work under individualized pacing.

9. ELEMENTARY SCHOOL SCIENCE EDUCATION CURRICULUM DEVELOPMENT.
Contact: Mrs. Chu-Sheng Yeh Cheng, Director-General, Department of Elementary Education, Ministry of Education, Republic of China, Taipei, Taiwan.

Science Units grades 1-6 from the present curriculum and adaptation of appropriate materials from Japanese and other foreign curriculum projects.

10. ELEMENTARY SCHOOL SCIENCE PROJECT OF THE SCIENCE EDUCATION CENTER, UNIVERSITY OF THE PHILIPPINES (SEC).
Project Director: Dolores F. Hernandez, Science Education Center, University of the Philippines, Diliman, Quezon City, Philippines.

Elementary Science, grades 1-6, age 7-12.

11. ENVIRONMENTAL AND INTEGRATED SCIENCE PROJECTS FOR PHILIPPINE SCIENCE EDUCATION (UNICEF/NSDB-ASSISTED PROJECT).
Project Director: Mr. Mauro Gonzales, Executive Secretary, Coordinating Committee, UNICEF-assisted Science Education Project, National Science Development Board, P.O. Box 3596, Manila, Philippines.

Primary and secondary school science for all elementary and high schools in the Philippines.

12. GENERAL SCIENCE PROJECT OF THE INSTITUTE FOR PROMOTION OF TEACHING SCIENCE AND TECHNOLOGY.
Project Director: Mr. Sanan Sumitra, Director, Institute for Promotion of Teaching Science and Technology, c/o Physics Building, Chulalongkorn University, Bangkok, Thailand.
General Science grades 7-12; ages 13-18 years.

13. INTEGRATED SCIENCE (LOWER SECONDARY SCHOOL).
Project Director: Mr. Chang Kwai, Education Officer (Science) I, School Division, Ministry of Education, Federal House, Kuala Lumpur, Malaysia.

Integrated Science (mainly physics, chemistry and biology); Forms I to III (Grade 7-9); all ability levels.

14. INTEGRATED SCIENCE CURRICULUM PROJECT.
Project Director: Dr. Yoshinobu Kakiuchi, Professor of Physics, The Institute for Solid State Physics, Tokyo University, 7-22-1, Roppongi, Minato-ku, Tokyo, Japan.
Kindergarten to 7th grades in public schools.

15. PROJEK KHAS.
Project Director: Mr. Abu Hassan bin Ali (Mr. Abu Hassan), Senior Organizer, Science, Pusat Sains, Kementerian Pelajaran, Batu 2 1/2 Jalan Damansara, Kuala Lumpur, Malaysia.
Science and mathematics for Standards 1-6 (Grade 1-6), for children of general ability in the 5 to 11 year old age range.

16. SCIENCE EDUCATION PROJECT, MINISTRY OF EDUCATION, SEOUL.

Project Director: Byung Kwon Ha, Professor, Room 914, Unified Government Building, Seoul, Korea.

Natural Science, grades 1-6, ages 6-12, all abilities; General Science, grades 7-9, ages 13-15, all abilities.

17. SCIENCE TEACHING ENRICHMENT PROGRAM (STEP).
Project Director: His Majesty's Government of Nepal, Ministry of Education, Curriculum Development Center.

Combines the study of general science and hygiene/physiology in classes IV through X. The students range in age from 10 to 18. For the majority of students it is their first and last science course.

18. UNICEF-ASSISTED PILOT PROJECT FOR THE IMPROVEMENT OF SCIENCE TEACHING AT ALL LEVELS OF SCHOOL EDUCATION (UNICEF PROJECT).
Project Director: Dr. M. C. Pant, Head of Department, Department of Science Education, National Council of Educational Research and Training, N.I.E. Bldgs., Sri Aurobindo Marg, New Delhi 16, India.

Integrated Science for classes I to V; age 6-11 years.

AUSTRALIAN AREA

19. AUSTRALIAN SCIENCE EDUCATION PROJECT (ASEP).
Project Director: H. O. Howard, 11 Glenbervie Road, Toorak Victoria 3142, Australia.

Science, grades 7-10 or 8-10 as appropriate in the junior secondary schools in the States of Australia. Majority from 11 to 16 years.

20. JUNIOR SECONDARY SCIENCE PROJECT (JSSP).
Project Director: Dr. W. C. Radford, Director, Australian Council for Educational Research, Frederick Street, Hawthorn, Australia 3122.

Science, embracing aspects of chemistry, physics, biology, geology and astronomy; grades 7-8, ages approximately 11-13 years.

21. THE SCIENCE FOUNDATION FOR PHYSICS INTEGRATED AND COORDINATED SCIENCE TEXTBOOK PROJECT FOR THE NEW SOUTH WALES SIX YEAR SCIENCE COURSES.
Project Director: Professor Harry Messel, Head of the School of Physics and Director of the Science Foundation for Physics within the University of Sydney, Sydney, 2006, N.S.W., Australia.

Integrated science covering the fields of physics, chemistry, biology, geology and astronomy for Forms I, II, III and IV (ages 12, 13, 14 and 15) at Modified, Ordinary Credit and Advanced Level. Coordinated Science covering the fields of physics, chemistry, biology and geology separately for ages 16 and 17 from ordinary to essentially advanced level.

22. SECONDARY SCIENCE PILOT SYLLABUS.
Project Director: Secondary Science Syllabus Review Committee; D. A. Mitchell, Chairman.

All aspects of science at secondary level.

CARIBBEAN AREA

23. CENTER FOR EDUCATIONAL DEVELOPMENT OVERSEAS, UNIVERSITY OF THE WEST INDIES CARIBBEAN REGIONAL SCIENCE PROJECT (CRSP). ALSO WEST

INDIAN SCIENCE CURRICULUM INNOVATION PROJECT (WISCIP).
Project Directors: Senior Consultant, A. J. Mee, O.B.E., 9 Gordon Road, Edinburgh EH 126 MB, Scotland.
Local Consultant: P. S. Adey, University of the West Indies, Institute of Education, P.O. Box 64, Bridgetown, Barbados.

Integrated Science; 11-14 year age range; all ability groups.

24. UNIVERSITY OF THE WEST INDIES SCIENCE EDUCATION PROJECT, MONA.
Project Director: J. F. Reay, Department of Physics, University of the West Indies, Mona, Kingston 7, Jamaica.

Integrated science; grades 7-9; ages 12-15; all abilities.

EUROPE

25. CEDO'S PROGRAM IN INTEGRATED SCIENCE TEACHING.
Contact: Director, Centre for Educational Development Overseas, Tavistock House, Tavistock Square, London W.C.1.

Integrated science; primary and secondary levels.

26. CONSERVATION EDUCATION PROJECT.
Project Director: Dr. P. J. Kelly, Centre for Science Education, Chelsea College, Bridges Place, London S.W.6, England.

Science subjects where it satisfies the current trend towards emphasising social implications, but also in geography, history and economics.

27. INVESTIGATIONS OF THE METHODOLOGY AND STRATEGY FOR THE CONSTRUCTION OF INTEGRATED SCIENCE CURRICULA.
Contact: Dr. Peter Haussler or Prof. Karl Frey, Institut fur die Padagogik der Naturwissenschaften an der Christian-Albrechts-Universitat Kiel, 23 Kiel, Olshausenstr. 40-60, West Germany.

Multidisciplinary from psychology, pedagogy, sociology, biology, chemistry and physics.

28. NATURWISSENSCHAFTLICHER UNTERRICHT IN DER GRUNDSCHULE (NUG) (SCIENCE TEACHING IN THE ELEMENTARY SCHOOL).
Project Director: Dr. K. Sprekelsen, Professor Gesamthochschule Kassel, Heinrich-Plett-Strabe 40, 3500 Kassel, West Germany.

Elementary science (particularly physics and chemistry); grades 1-14; age 6-10 years; all ability levels.

29. NUFFIELD PHYSICAL SCIENCE COURSE.
Project Director: Dr. J. E. Spice, Chelsea College Centre for Science Education, Bridges Place, S.W.6, London, England.

Physical science; 16-18 years old; top third of population.

30. NUFFIELD SECONDARY SCIENCE.
Project Director: Mrs. H. Misselbrook, Organizer, Nuffield Secondary Science Project, Center for Science Education, Bridges Place, London S.W.6, England.

Integrated science; ages 13-16, mainly physics, chemistry, biology, geology.

31. THE OPEN UNIVERSITY IN GREAT BRITAIN (Science Foundations Course and Technology Foundation Course)

Contact: Office of the Vice Chancellor, Open University, Bletchley, Buckinghamshire, England.

For people who are generally over 21 years of age and working full-time and do not necessarily have good secondary school qualifications.

32. PROGRAMMED MATERIALS FOR THE HIGHLANDS AND ISLANDS OF SCOTLAND (PROJECT PHI).
Project Director: Mr. Martyn Roebuck, Programmed Learning Research Unit, Department of Education, University of Glasgow, Glasgow G12 8QQ, Scotland.

    Parts of "Integrated Science" as set out in the Scottish Education Department Curriculum Paper No. 7; all pupils aged 12-14 years.

33. SCHOOLS COUNCIL INTEGRATED SCIENCE PROJECT (SCISP): "PATTERNS".
Project Directors: Mr. William C. Hall and Mr. B. S. Mowl, Centre for Science Education Annexe, 90 Lillie Road, London, SW6 7SS, England.

    Integrated Science for 13-16 year old students leading to a double certification GCE O level.

34. SCIENCE 5/13.
Project Director: Mr. L.F. Ennever, 9 Tyndall Avenue, Bristol BS8 ITQ, England.

    Science; ages 5-13; all ability levels.

35. SCOTTISH SECONDARY SCIENCE SCHEMES.
Project Director: A. W. Jeffrey, H.M.I., Scottish Education Department, 5 Randolph Cres., Edinburgh EH3 7th, Scotland.

    Physics, chemistry, biology and various integrated courses for students in the age group 12-18.

MIDDLE EAST AREA

36. AGRICULTURE AS ENVIRONMENTAL SCIENCE.
Project Director: A. Blum, Project Director, Curriculum Center, Ministry of Education and Culture, 4, Mamilla Road, Jerusalem, Israel.

    "Let's grow plants" grade 7 or 8 (Course A for Junior High Schools)
    "Let's protect plants", "Let's fight hunger", "Let's Grow bees", "Let's grow chicks" grade 8 or 9 and "Growth regulators" grade 10 or 11 (Laboratory Block).

37. ISRAEL ELEMENTARY SCIENCE PROJECT (MATAL).
Project Director: Dr. David Chen, Ph.D., 20, Moskovitz Street, Rehovoth, Israel.

    Science; K-6; diverse population with a large number of culturally deprived students.

38. PHYSICS – CHEMISTRY PROJECT (IN ISRAEL).
Project Directors: Nathan Orpaz and Dr. Ruth Ben-Zvi, Curriculum Center, Ministry of Education and Culture, Jerusalem, Israel.

    Physics-Chemistry; grades 7-9; ages 12-15.

SOUTH AMERICAN AREA

39. FUNDACAO BRASILEIRA PARA O DESENVOLVIMENTO DO ENSINO DE CIENCIAS (FUNBEC).
Project Director: Dr. Ernesto Giesbrecht, Scientific Director, Caixa Postal 91 – Sao Paulo, Brasil.

    Improving science teaching at all levels.

UNESCO

40. UNESCO'S PROGRAM IN INTEGRATED SCIENCE TEACHING.
Project Director: Mrs. Sheila M. Haggis, Division of Science Teaching, UNESCO, Place Fontenoy, 75 - Paris 7, France.

Unified science; grades 1 to 9; all ability levels.

UNITED STATES

41. BUILDING EDUCATIONAL BRIDGES BETWEEN SCIENCE AND THE HUMANITIES.
Project Director: Dr. V. Lawrence Parsegian, Rensselaer Professor, Rensselaer Polytechnic Institute, Troy, New York 12181, U.S.A.

Multidisciplinary project designed to develop teaching materials and approaches that interrelate the physical, biological, social sciences and the humanities and fine arts, for use in courses of study that may be junior or senior college.

42. CENTER FOR ENVIRONMENTAL EDUCATION, MINNESOTA ENVIRONMENTAL SCIENCES FOUNDATION, INCORPORATED (MESFI).
Project Director: Robert E. Collins, Director, 5400 Glenwood Avenue, Minneapolis, Minnesota 55422, U.S.A.

Embraces several subject areas as they pertain to matters of environmental management. K-college, teachers, youth and organization leaders.

43. CONCEPTUALLY ORIENTED PROGRAM IN ELEMENTARY SCIENCE (COPES).
Project Directors: Professor Morris H. Shamos, Professor of Physics; and Professor J. Darrell Barnard, Professor of Science Education, New York University, 4 Washington Place, New York, New York 10003, U.S.A.

All areas of science developed for K-6 (ages 5-12), using conceptual themes.

44. CONSERVATION CURRICULUM IMPROVEMENT PROJECT (CCIP).
Contact: Albert H. H. Dorsey, Chief Supervisor, Curriculum Development Section, South Carolina State Department of Education, Room 801, Rutledge Building, Columbia, South Carolina 29201, U.S.A.

Various subject matter areas at all levels of education in the areas of general science, biology, social studies, home economics and outdoor education.

45. COOPERATIVE GENERAL SCIENCE PROJECT (CGSP).
Project Director: Dr. O. P. Puri, Director CGSP, Clark College, Atlanta, Georgia 30314, U.S.A.

To develop materials in physical and biological science using historic, conceptual, philosophical and humanistic approaches for college level students.

46. THE DEVELOPMENT AND IMPLEMENTATION OF A FOUR-YEAR, UNIFIED, CONCEPT CENTERED SCIENCE CURRICULUM FOR SECONDARY SCHOOLS.
Project Director: Carl H. Pfeiffer, Science Department Chairman, Monona Grove High School, 4400 Monona Drive, Monona, Wisconsin 53716, U.S.A.

To develop and implement a unified concept-centered science curriculum to replace all subject oriented science courses at the secondary school level.

47. EARTH AND SPACE SCIENCE ENRICHMENT PROJECT.
Project Director: William H. Bolles, Science Education Adviser, Department of Education,

Harrisburg, Pennsylvania 17126, U.S.A.

Earth and Space Science; Grade 9 or above; various ability levels.

48. EARTH SCIENCE EDUCATION PROGRAM (ESEP):
EARTH SCIENCE TEACHER PREPARATION PROJECT (ESTPP),
ENVIRONMENTAL STUDIES PROJECT (ES),
EARTH SCIENCE CURRICULUM PROJECT (ESCP).
Project Directors: William D. Romey, Executive Director, P.O. Box 1559, Boulder, Colorado 80303, U.S.A.

Co-Directors: John F. Thompson (ESTPP), Robert E. Samples (ES).

ESTPP – Earth science teachers and teacher trainers for elementary school, secondary school, and college teachers; ES – Environmental studies in the broad sense for students K-16; ESCP – Earth science, grades 7-10.

49. ELEMENTARY SCIENCE STUDY (ESS).
Project Director: Christopher Hale, 55 Chapel Street, Newton, Massachusetts 02160, U.S.A.

Science K-9, all students.

50. ENVIRONMENTAL EDUCATION CURRICULUM DEVELOPMENT PROJECT.
Contact: Karen B. Wiley, Social Science Education Consortium, Inc., 855 Broadway, Boulder, Colorado 80302, U.S.A.

Uses high school students in the design of community experiments with alternatives in Boulder's physical and human environment. Materials produced have a strong social studies emphasis for kindergarten through high school.

51. ENVIRONMENTAL EDUCATION PROGRAM.
Project Directors: Marvin Meissen, Coordinator of Science and David Archbald, Environmental Consultant, Madison Public Schools, P.O. Box 2189, Madison, Wisconsin 53703, U.S.A.

To develop a K-12 comprehensive environmental education programme that utilizes community resources from industry, government, university and agencies sources in a systematic manner.

52. ENVIRONMENTAL EXPERIMENTS PROGRAM (EEP).
Project Director: Mr. Courtland S. Randall, Chairman, Information and Exhibits Division, Oak Ridge Associated Universities, Inc., P.O. Box 117, Oak Ridge, Tennessee 37830, U.S.A.

To incorporate hands-on assay methods in dealing with the important subject of environmental monitoring from the 9th grade level through undergraduate college level.

53. ENVIRONMENTAL STUDIES PROGRAM.
Project Director: William A. Reiners, Associate Professor of Biology, Director, Environmental Studies Program, Dartmouth College, Hanover, New Hampshire 03755, U.S.A.

To awaken a large number of students and potential leaders in a wide variety of fields to the complexities of environmental matters and to educate them on the scientific, social and humanitarian aspects of these problems.

54. ERC SCIENCE PROGRAM.
Project Director: Dr. Gary Dean Day, Director, ERC Science Program, Educational Research Council of America, 312 Rockefeller Building, 614 Superior Avenue, N.W., Cleveland, Ohio 44113, U.S.A.

Life Science Programme – Grade 7; Science Problems – Grades 11-12, Students who do not take physics and chemistry.

55. THE ETHICS OF ENVIRONMENTAL CONCERN: A RATIONALE AND PROTOTYPE MATERIALS FOR ECOLOGICAL EDUCATION IN THE HUMANISTIC TRADITION.
Contact: Rodney F. Allen, Project Director, Asst. Professor, Social Studies Education, The Florida State University, Tallahassee, Florida 32303, U.S.A.

To develop a rationale for environmental education, stressing attitudes and value commitments, rationale and performance-centered decision-making.

56. FOUNDATIONAL APPROACHES IN SCIENCE TEACHING (FAST).
Project Director: Dr. Francis M. Pottenger, III, Director FAST Project, Science Faculty Chairman, University Laboratory School, 1776 University Avenue, Honolulu, Hawaii 96822.

A three-year sequential laboratory and field-centered science programme for grades 7-9 which develops an understanding of foundational concepts and methodologies of the physical, earth, and biological sciences.

57. HUMANISTIC APPROACH TO NATURAL SCIENCE (HANS).
Project Director: James V. Connor, Natural Science Department Head, Allentown College, Center Valley, Pennsylvania 18034, U.S.A.

Humanistic refers both to a focus on major figures of science as true individuals as well as to an emphasis on the interconnection of science and the humanities for average college liberal arts majors.

58. IDEA CENTERED LABORATORY SCIENCE (I-CLS).
Project Director: Dr. W. C. Van Deventer, Professor of Biology (Science Education), Department of Biology, Western Michigan University, Kalamazoo, Michigan 49001, U.S.A.

Contains materials drawn from biology, chemistry, physics, and earth science directed towards interdisciplinary ideas.

59. IDEAS AND INVESTIGATIONS IN SCIENCE PROJECT (IIS) – AN APPROACH TO SCIENCE FOR THE EDUCATIONALLY UNINVOLVED.
Project Director: Harry K. Wong, Director, IIS Project, 570 Price Avenue, Redwood City, California 94063, U.S.A.

To develop appropriate science materials for use by educationally uninvolved students in grades 7 to 12.

60. INDEPENDENCE OUTDOOR LABORATORY.
Project Director: Charles T. Vizzini, Coordinator, Charlott-Mecklenburg Schools, P.O. Box 149, Charlotte, North Carolina 28201, U.S.A.

A study of the student's environment made alive through bringing more of this environment into an instructional programme for elementary and high school.

61. INDIVIDUALIZED SCIENCE (FORMERLY INDIVIDUALLY PRESCRIBED INSTRUCTION IN SCIENCE – IPI SCIENCE).
Project Director: Dr. Leopold E. Klopfer, Director, Individualized Science Learning Research and Development Center of the University of Pittsburgh, Pittsburgh, Pa. 15213, U.S.A.

General science, with major emphases placed on science as inquiry and on the individual's needs for knowledge and understanding which are relevant to current societal issues and relevant to himself, school grades K or 1 through 8.

62. INTERDISCIPLINARY APPROACHES TO CHEMISTRY (IAC).
Project Director: Dr. Marjorie Gardner, Professor, Chemistry Department and Science Teaching Center, University of Maryland, College Park, Maryland 20742, U.S.A.

This programme is modular in nature and specifically designed to attract the non-science major as well as those looking forward to careers in science or technology. It broadens the teaching of chemistry by bringing interdisciplinary areas such as biochemistry, geochemistry and environmental chemistry into the curriculum. Mainly 11th grade, but modules may be used in programme grades 9-13.

63. INTERDISCIPLINARY ENVIRONMENTAL EDUCATION K-12 (IEE PROJECT).
Project Directors: John Arena, IEE Project, 3600 S.W. College Avenue, Ft. Lauderdale, Florida 33314, U.S.A.

Interdisciplinary environmental education, K-12, all levels.

64. INTERMEDIATE SCIENCE CURRICULUM STUDY (ISCS).
Project Directors: Dr. David D. Redfield and Dr. William R. Snyder, Co-Directors of ISCS, Rm. 415, 415 North Monroe Street, Tallahassee, Florida 32301, U.S.A.

Science for grades 7, 8 and 9; all ability levels.

65. INTRODUCTORY PHYSICAL SCIENCE (IPS).
Project Director: Dr. Uri Haber-Schaim, Physical Science Group, Newton College of the Sacred Heart, 885 Centre Street, Newton, Massachusetts 02159, U.S.A.

The major emphasis in the course is the study of matter. The course has been extensively used in grades 8 and 9 with students who have a wide range of abilities.

66. MAN AND HIS ENVIRONMENT.
Contact: Dr. Adrian M. Hofstetter, Project Director, Professor of Biology, Lemoyne-Owen College, 807 Walker, Memphis, Tennessee 38126, U.S.A.

The purpose is to increase community awareness of the environmental problems (industrial pollution) and provide means of stemming the forces causing their environmental deterioration.

67. MASSACHUSETTS – NASA AEROSPACE CURRICULUM RESOURCE GUIDE.
Contact: Mr. John W. Packard, 182 Tremont Street, Boston, Massachusetts 02111, U.S.A.

This project provides assistance to teachers in Grades K-12 to identify and relate recent advances in aerospace science and technology to the basic subject matter areas.

68. MILLBURN UNIFIED SCIENCE.
Project Director: Leonard C. Blessing, Science Department Head, Millburn Senior High School, 462 Millburn Avenue, Millburn, New Jersey 07041, U.S.A.

To present science as an interdisciplinary subject, rather than as biology, physics and chemistry. To give a deeper understanding of the interrelatedness of science than is possible in single discipline courses.

69. MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT (MINNEMAST).
Project Director: James H. Werntz, Jr., Professor of Physics, Director, Center for Educational Development, University of Minnesota, Minneapolis, Minnesota 55455, U.S.A.

To produce coordinated mathematics and science curriculum for grades K-6 and to develop process acquisition, attitudinal changes and scientific literacy.

70. MINNESOTA PLAN FOR ELEMENTARY AND SECONDARY ENVIRONMENTAL EDUCATION.
Contact: Mr. John C. Miller, Project Director, Minnesota Department of Education and Natural Resources, 644 Capitol Square Building, St. Paul, Minnesota 55101, U.S.A.

The project aims to develop, field test, and implement an interdisciplinary K-12 instructional program that will bring Minnesota students to an understanding of natural processes and man's natural and social position among them.

71. MODEL EDUCATIONAL PROGRAM IN ECOLOGY, KINDERGARTEN THROUGH ADULT EDUCATION.
Project Directors: David P. McLaren, Instructional Specialist, 450 North Grand Avenue, Los Angeles, California 90012, U.S.A.
Sid Sitkoff, Instructional Specialist, North Field Service Center, 8111 Calhoun Avenue, Panorama City California 91402, U.S.A.

To develop, implement, and monitor a comprehensive program in ecology (environmental education) from kindergarten through adult education.

72. NASA SPACE RELATED CURRICULUM SUPPLEMENTS.
Contact: Dr. Frederick B. Tuttle, Director of Educational Programs, National Aeronautics and Space Administration, Washington, D.C. 20546, U.S.A.

This project produces aerospace-related publications to help enrich and update the teaching of the sciences and mathematics in secondary schools, including grades 8 through 14.

73. NATIONAL ENVIRONMENTAL EDUCATION DEVELOPMENT (NEED).
Project Director: Vernon C. Gilbert, Jr., Chief, Office of Environmental Interpretation, National Park Service, Washington, D.C. 20240, U.S.A.

To assist school children in coming to grips with their own world by way of a valid environmental ethic.

74. NATURAL SCIENCE CURRICULUM FOR THE NON-SCIENCE MAJOR.
Project Director: Gus John Demas, Professor, Department Chairman, Division of General Education, Center Campus, Macomb County Community College District, 16500 Hall Road, Mt. Clemens, Michigan 48043, U.S.A.

Physical and biological science integrated through the themes of "What Am I" and "Who Am I"; college level, transferable science credit for the non-science major at various ability levels (remedial to college-parallel).

75. NEBRASKA PHYSICAL SCIENCE PROJECT (NPSP).
Project Director: Dr. Donald W. McCurdy, Associate Professor of Secondary Education, University of Nebraska, Lincoln, Nebraska 68508, U.S.A.

To make possible the situation whereby teachers, scientists, and education specialists could work together to devise a program which would improve the teacher-learning of physics and chemistry.

76. PARKWAY PROGRAM.
Contact: Leonard Finklestein, Director of School, The Franklin Institute, 20th Street and the Parkway, Philadelphia, Pa. 19103, U.S.A.

"The high school without walls" has been an administrative structure that allows students to develop their own curriculum each semester.

77. PENNSYLVANIA NUCLEAR SCIENCE PROJECT (PNS).
Project Director: Mr. John J. McDermott, Science Education Advisor, Bureau of General and Academic Education, Pennsylvania Department of Education, P.O. Box 911, Harrisburg, Pennsylvania 17126, U.S.A.

To provide an enrichment program for science-oriented students of high academic ability.

78. PHYSICAL SCIENCE II (PS–II).
Project Director: Dr. Uri Haber-Schaim, Physical Science Group, Newton College of the Sacred Heart, 885 Centre Street, Newton, Massachusetts 02159, U.S.A.

To develop a second year course in physical science for use in the junior-senior high school as a sequel to IPS.

79. PORTLAND PROJECT.
Project Directors: Michael Fiasca and Karl Dittmer, School of Education, Portland State University, P.O. Box 751, Portland, Oregon 97207, U.S.A.

Biology, chemistry, physics, environmental science and behavioral science for 14-17 year olds.

80. PREPROFESSIONAL INDIVIDUALLY PRESCRIBED INSTRUCTION CURRICULUM (PIPI).
Contact: Kenneth A. McCollom, College of Engineering, Office of the Dean, Oklahoma State University, Stillwater, Oklahoma 74074, U.S.A.

Written, oral, graphic, and computer communications. The self-paced study program integrates instructional activities across these four subject areas.

81. PROJECT I-C-E (INSTRUCTION-CURRICULUM-ENVIRONMENT).
Project Directors: Robert J. Warpinski, Director, and Robert W. Kellner, Assistant Director, 1927 Main Street, Green Bay, Wisconsin 54301, U.S.A.

To improve instruction and curriculum in environmental education, to ultimately effect change of attitudes and values of students.

82. PROJECT PHYSICS.
(formerly Harvard Project Physics).
Project Directors: Dr. F. James Rutherford, Executive Director, Project Physics, School of Education, Press Building, New York University, New York City, New York 10003, U.S.A. Co-Directors: Dr. Gerald Holton and Dr. Fletcher Watson, Longfellow Hall, Harvard University, Cambridge, Massachusetts 02138, U.S.A.

To develop a well-tested introductory course in physics in relation to the humanities and society.

83. "PROJECT SUCCEED" SUCCESSFUL UTILIZATION OF CORRECTED CURRICULUM ERASES EDUCATIONAL DEFICIENCIES.
Project Director: H. G. Hollingsworth, Jr., Director, Office of Adjunct Education, State Department of Education, Columbia, South Carolina 29201, U.S.A.

To develop and make available at the high school level, a relevant program of education for underachieving, noncollege-bound students with high dropout potential.

84. PROJECT USE (UPDATE SPACE EDUCATION).
Project Director: John C. Thurber, In-service Education, Palm Beach County Schools, P.O. Box 2469, West Palm Beach, Florida 33402, U.S.A.

To update space science in-service training of teachers by producing a series of seven videotapes on space science for in-service education of teachers.

85. PUNAHOU ENVIRONMENTAL EDUCATION PROJECT.
Project Director: Siegfried Ramler, Director of Instructional Services and Coordinator of Curriculum, Punahou School, Honolulu, Hawaii 96822, U.S.A.

Environmental education, K-12, Punahou School, (College preparatory).

86. QUANTITATIVE APPROACH TO ELEMENTARY SCHOOL SCIENCE (QS).
Project Director: Clifford E. Swartz, Professor of Physics, Physics Department, State University of New York, Stony Brook, New York 11790, U.S.A.

Basic science for Grades 3-6, remedial for grades 7 and 8.

87. QUANTITATIVE PHYSICAL SCIENCE (QPS).
Project Director: Dr. Sherwood Githens, Jr., Professor of Science Education, Duke University, College Station, Durham, N.C. 27708, U.S.A.

QPS was originally intended for age-14 junior-high students. Experience has shown that its content and method are suitable for a much wider range of ages, including adults. The program can be adjusted to the learning rates and degrees of preparation of slow, average, or talented students.

88. SCHOOL/COMMUNITY ENVIRONMENTAL STUDIES PROJECT (ESP).
Project Director: Will Hon. Director, Environmental Studies Project, Carteret County Schools, P.O. Drawer 600, Beaufort, North Carolina 28516, U.S.A.

Language arts, social studies and ecology; grades 11 and 12, full range of IQ's and abilities and past performance, the only criterion being interest.

89. SCIENCE – A PROCESS APPROACH (AN ELEMENTARY SCHOOL SCIENCE CURRICULUM PROGRAM DEVELOPED BY THE COMMISSION ON SCIENCE EDUCATION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE).
Project Director: John R. Mayor, Director; Arthur H. Livermore, Deputy Director; 1515 Massachusetts Avenue, N.W., Washington, D.C. 20005, U.S.A.

Science for kindergarten through grade 6. Some schools are using the materials also in grades 7 and 8.

90. SCIENCE COURSES FOR BACCALAUREAT EDUCATION (INTRODUCTION TO NATURAL SCIENCE).
Project Director: Dr. V. L. Parsegian, Chair of Rensselaer Professor, Rensselaer Polytechnic Institute, Troy, New York 12181, U.S.A.

To provide teaching materials and guides whereby the physical and life sciences could be taught in an integrated form, emphasizing concepts and social interests rather than developing problem-solving skill, suitable for both non-science and science college freshmen and sophomores.

91. SCIENCE CURRICULUM IMPROVEMENT STUDY (SCIS).
Project Director: Robert Karplus, Professor of Physics, Associate Director of The Lawrence Hall of Science, University of California, Berkeley.

Sequential physical and life science curriculum suggested for grades K-6.

92. SCIENCE FOR THE SEVENTIES (SFTS).
Project Director: Dr. Irvin T. Edgar, Science Education Adviser, Bureau of General and Academic Education, Box 911, Harrisburg, Pennsylvania 17126, U.S.A.

This project has produced materials to provide direction for elementary teachers in teaching science through the provision of illustrative science materials. It provides a variety of activities and procedures to be adapted by the teacher to suit the individual classroom.

93. SCIENCE, NATURE AND THE SURVIVAL OF MAN (SNSM).
Project Director: Dr. Irvin T. Edgar, Science Education Adviser, Bureau of General and Academic Education, Box 911, Harrisburg, Pennsylvania 17126, U.S.A.

SNSM was initiated to provide guidance and materials for science instruction of secondary school students who are not science majors. The primary emphasis is on science-related social issues of current concern including pollution and population problems.

94. SECONDARY SCHOOL SCIENCE PROJECT (SSSP).
Project Director: Dr. George J. Pallrand, 10 Seminary Place, Rutgers University, The State University of New Jersey, New Brunswick, New Jersey 08903, U.S.A.

Time, Space and Matter . . . investigating the physical world is a science course which emphasizes doing science rather than recounting its achievements. The course consists of nine interrelated investigations which enable the student to learn something about the nature and history of the physical world through direct observation and inference.

95. TAKE A LOOK! COMMUNITY ENVIRONMENTAL EVALUATION.
Project Director: Hilton Power, Coordinator of Special Projects, Division of Adult Education, Box 3274, University Station, Laramie, Wyoming 82070, U.S.A.

Creation of a more environmentally aware population in a very practical sense. Medium used – community conferences.

96. TECHNOLOGY FOR CHILDREN PROJECT (T4CP) (T4C).
Project Director: Dr. Fred J. Dreves, Jr., Ed.D., Director, Technology for Children Project, Division of Vocational Education, Department of Education, 225 West State Street, Trenton, New Jersey 08625, U.S.A.

To develop individualized teaching-learning in the elementary school classrooms of New Jersey at the K-6 level of career education.

97. TOTAL EDUCATION IN THE TOTAL ENVIRONMENT (T.E.T.E.).
Project Director: William R. Eblen, P.O. Box 113, Wilton, Conn. 06897, U.S.A.

Multidisciplinary approach to redirecting the entire curriculum around The Ecology of Man (emphasis on natural sciences, social sciences, creative arts, language arts); K-Adult Education; no limitations.

98. UNIFIED SCIENCE AND MATHEMATICS FOR ELEMENTARY SCHOOLS (USMES).
Project Director: Earle L. Lomon, Professor of Physics, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 6-304, Cambridge, Massachusetts 02138, U.S.A.

Integrated math-science and social science; Grades 1-6 (and 7-9 in part).

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